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THE PEAK AND DECLINE OF NIGERIAN OIL: HOW SOON?

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Abstract

Recent increase in the economic importance of Crude Oil in Nigeria had resulted in the research and understanding of the availability and recoverability of the resources. The peak of Nigeria oil production, followed by an irreversible decline, will be a watershed in Nigeria history. Production data from 1958-2003 were used for the estimation of peak, based on the Energy Information Agency (EIA) methodology of growth rate of 2, 3, and 4 % per year and a decline of Reserve to Production (R/P) ratio of 10. Combining these methodology "SCENARIOS" with the oil production numerical data, we have arrived at (2033-2065) a span of 32 years as a probable time of peak for Nigerian oil. We do recognize, however, given all possible variables, it is likely that this date (2033-2065) may be wrong. The question is how far wrong? We believe, it is reasonably close and further studies will help narrow whatever error exists. Importantly, the peak of oil production may occur within the lifetime of most people living today.

Introduction

This work tries to explain the relationship between discovery and production of oil, with the hope that it will lead to a better understanding of its future availability (forecast and peak of production evaluation). This is very important because crude oil is the most important fossil fuel, the World and Nigerian economies are dependent on it. It account for over 80% of Nigerian export revenue. Almost all the crude oil exploration and production in Nigeria are produced in the Niger Delta oil province, which is the seventh largest oil-producing basin in the World (EIA, 2004).

Objective

The objectives of this study include;

- To possibly forecast the year of peak production, and
- To forecast the decline rate.

Brief geology of Niger delta

Crude oil Production in Nigeria is produce in the Niger Delta of Nigeria. The Tertiary Niger delta is one of the major regressive deltaic sequences in the World. It is also regarded as one of the highly productive sedimentary basins in the Sub-Saharan Africa, due to its rich hydrocarbon content. The Delta with over 12,000m thick and covers an area of about 75,000square kilometer, extends from the Calabar Flank and the Abakaliki Trough in the Eastern Nigeria to Benin flank in the west and opens to the Atlantic Ocean in the south. It protrudes into the Gulf of Guinea and an extension from the Benue Trough and Anambra Basin province in the North. The Niger Delta is a classical example of a Delta formation with a unique geological nature and high hydrocarbon (petroleum) production with over 1500 oil fields (Schlumberger, 1985).

The Niger Delta has a defined Stratigraphic nomenclature like many other Deltas, because of the coalition of its sediments. It is a sedimentary structure formed as a complex regressive off lap sequence of clastic sediments. But evidence from deep wells in the Delta has shown that the thick wedge of Delta sediments can be considered to consist of three units (a triparte lithostratigraphic succession in which regressive sequence is properly defined). The Tertiary Stratigraphy of the Niger Delta has been described and defined by Short and Stauble (1967), who recognized three distinct facies belts (Formation): The prodelta facies, The Paralic delta fronts facies and the Continental delta top facies . In ascending order, these formations are the Akata, Agbada and Benin Formations. The stratigraphic succession is an overall coarsening-upward sequence of more than 12,000m thick. Figure 1 is the map Nigeria, showing the Study Area (Niger Delta).

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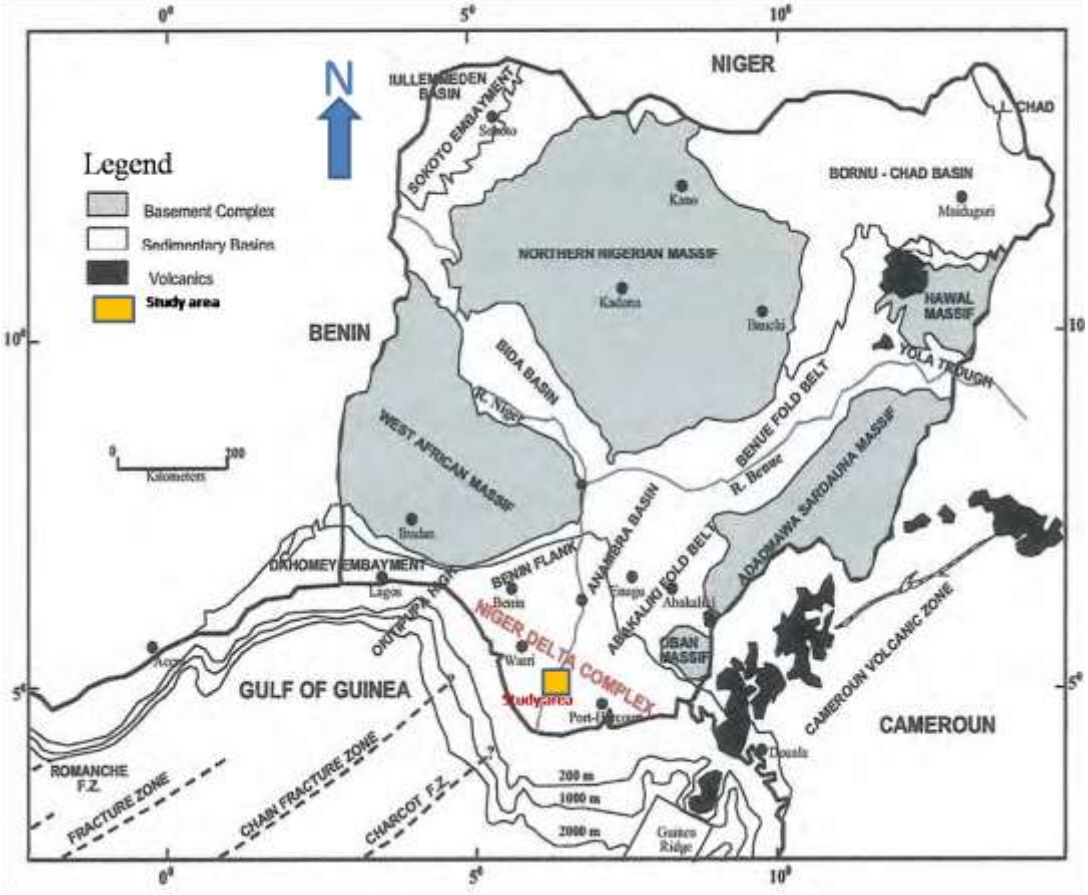
Figure 1: Map of Nigeria, showing Niger delta basin and the location of study area (modified after Whiteman, 1982).



Origin of oil forecast

In 1956, a Geologist M. King Hubbert, working with the Shell, in his famous 1956 paper " Nuclear Energy and the Fossil Fuel" predicted that Texas (US) oil production would peak in 1965, if the assumed Ultimate cumulative production were 150 billion barrel or 1970, if the assumed ultimate Cumulative production were 200 billion barrels. The US production peaked in 1970. He also predicted that proved reserve of oil would peak before production peak, and the Texas (US) proved reserves did so in 1969 (figure 2). The Hubbert – US experience used in creating his famous curve that predicted the US oil production peak, ushered in the permanent oil shock era and the finite nature of crude oil (Ivanhoe, et al, 1995).

Texas (US) production started in1889 and then peaked in 1970 i.e. 83 years from start to peak and then Texas oil production has obstinately declined since the peak (API, 1994; Duncan, 1995a). According to Duncan, 1995a, Mexican oil production started in 1901, it peaked sharply in 1921 to mark Mexico's "first oil boom". Although the 1921 peak is small compared to recent rates, the production rates had reached its greatest in 1994 at 3.3 million barrels per day, details shows that Mexican oil production is now near its peak, and likely to fall even faster than that of Texas.

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The Norway oil production peaked in 2000 and the decline phase presumably started in 2002, while the UK oil production peaked in the year 1999. The production has been declining and in 2000, the decline could not be compensated by bringing new fields into production, since then total production has also been declining of about 8% from 1999 to 2000 production year (Werner, et al, 2002). According to Werner, et al, 2002, crude oil production from Prudhoe Bay in Alaska also peaked in 1989 and the following year, oil production declined.

Some authors also made prediction of World oil peak. There were indeed many claims during the 1970s that oil would run out by the end of the (20th) century or even before. However, there was also a common prediction that oil production would peak around the end of the century, not run out, and this was the view taken by almost reputable organizations. It now appears this prediction would have been extremely accurate if it was not for the slowdown in production caused by the 1970s oil shocks. People remember the forecasts but, because they are unaware of the difference between oil peaking and oil exhaustion, they assume that all the predictions were that oil would run out by 2000 (Hubbert Curve, 2004). Prominent among these World prediction of peak oil production are summarized in Table 1 (Hubbert Curve, 2004)

More oil producing countries are reaching their peak of production in spite of very favourable economic conditions i.e. high prices of crude, and the fact that oil industry is spending much money and using all available high technologies to explore for oil in unfavourable area (Deep and Ultra deep offshore) might be interpreted as the industry's admission of the fact that even less oil is found at other (easier to access) places (Werner, et al, 2002).

In Nigeria, Oloibiri can be said to be a good example of a field, where oil has peaked and declined, even though, no data to substantiate this fact. Production started in Oloibiri in 1958, peaked in the 80"s and started declining. Presently, Oloibiri can be said to be the Nigerian equivalent of Texas (US) experience of 1970, predicted by M. King Hubbert in his popular 1956 "Nuclear Energy and the Fossil Fuel".

Table 1: Summarized table, showing various World Peak of Oil Production.

Date of Forecast	Source	Forecast Date of Conventional Peak	Assumed Ultimate
1972	ESSO	"Oil to become increasingly scarce from the year 2000"	2100 Gb
1972	Report for the UN Conf. on Human Environment	"likely that peak production will have been reached by the year 2000"	2500 Gb
1974	SPRU, Sussex University	n/a	1800–2480
1976	UK Dept of Energy	Peak: "about…2000"	n/a
1977	Hubbert	Peak: 1996	2000 Gb (Nehring)
1977	Ehrlich et al.	Peak: 2000	1900 Gb
1979	Shell	"…plateau within the next 25 years."	n/a
1979	BP (Oil Crisis…again?)	Peak (non-Communist world): 1985	n/a
1981	World Bank	"…plateau around the turn of the century"	1900 Gb

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1995	Petroconsultants	Peak: 2005	1800 Gb
1997	Ivanhoe	Peak: 2010	~ 2000 Gb
1997	Edwards	Peak: 2020	2836 Gb
1998	IEA: WEO 1998	Peak: 2014	2300 Gb ref. case
1999	USGS (Magoon)	Peak: ~ 2010	~ 2000 Gb
1999	Campbell	Peak: ~ 2010	2000 Gb (inc. polar deep)
2000	Bartlett	Peak: 2004 or 2019	2000 or 3000 Gb
2000	IEA: WEO 2000	Peak: "Beyond 2020"	3345 Gb (from USGS)
2000	2000 US EIA	Peak: 2016-2037	3003 Gb (from USGS)
2001	Deffeyes	Peak: 2003-2008	~ 2000 Gb
2002	Smith	Peak: 2011-2016	2180 Gb
2002	'Nemesis'	Peak: 2004-2011	1950-2300 Gb equiv.

(After Hubbert Curve, 2004)

Experience shows that production peak in an oil region happen when about half of the Ultimate recoverable oil has been extracted. Future oil production rates are limited by geological and technological constraints. In addition, economic factors influence future spending and production, and vice versa, once a growing industry or country arrives at a turning point (Peak) due to diminishing assets, this will influence the economic situation of the industry and the country as whole.

The life cycle of oil production

From the King Hubbert curve, production of crude can be viewed in three phases. Figure 3 shows Hubbert's curve. The standard Hubbert curve: for applications (the x and y scales) are replaced by (time and production scales).

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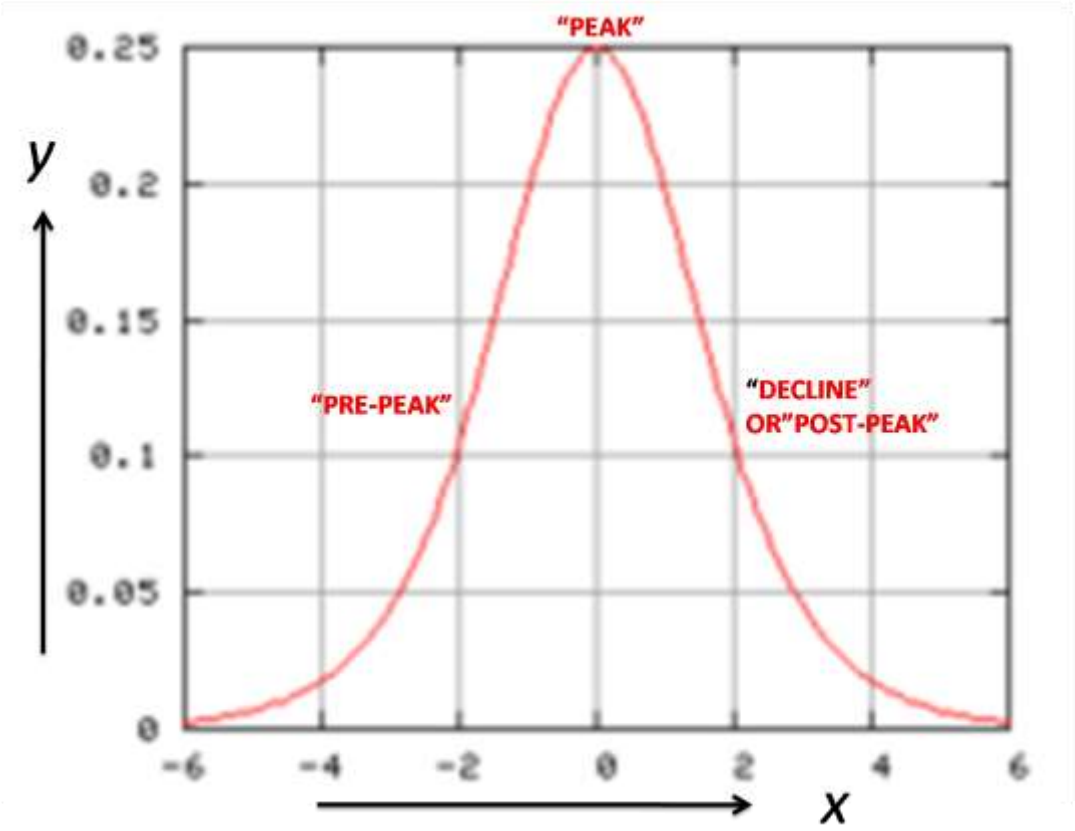

Figure 3: Hubbert's Curve showing the three phases (Hubbert Curve, 2004).

The three phases

The production profile over the life cycle of any oil region can be divided into three phases: The first phase is a phase of continual production increase ("Pre-Peak"); in the second phase, production is stagnant ("Peak" or "Plateau"); and finally we have a phase of continual declining production ("Decline" or "Post-Peak") (Figure 3)

These three phases of oil production constitute a general trend. In the following, we will explain this production profile and stages or phases.

Phase 1: "pre-peak"

In the early phase (PRE-PEAK) of production in any basin, an expansion of the production is quite easily done by adding new wells within already producing fields or by developing further fields. At this phase, the cost of production per barrels of crude is not high, production is on the increase. The reason is that, the reservoir pressure of the field at this point is very high; artificially method of recovery may not be necessary.

Phase 2: "Peak"

The longer the production goes on, the more the pressure in the oilfield drops while water level rises. Then at some point in time, the production rate begins to decrease. In this situation the addition of further wells within an already producing field lead to a further drop of pressure and therefore succeeds only for a very short time in upholding the rate of production. It then becomes increasingly difficult to extend the production of the whole region. Since more and more fields are developed into production, this may help to shape flatten the shape of the peak.

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Phase 3: "decline" or "post-peak"

Then at some point in time, the production starts declining in the already producing fields. The curve then gets so steep that it can no longer be compensated by the development of new fields. This is the time when the production of the whole region starts to enter the decline phase.

The implication of this phase to the producing fields or Countries is that, the production minimal can no longer be sustained. At this point, if production continues, the field will now decline gradually and with time, production will approach zero. The decline phase in any producing fields or areas is an irreversible phase in the life cycle of that field or area.

Research methodology

The numeric-forecasting model

Our method of data analysis is quantitative, using production data and mathematics to produce a forecast for the nation. This, so-called "guide" forecast, is a purely mechanical prediction of future production. The forecast can provide useful information about the shape of future oil production by providing a probable shape of the future production curve.

Given the test statistic to be employed in predicting the future cumulative production of crude is a multiple regression analysis, the model is specified as follow;

$$\mathbf{A_t = A_{t-1} - B\,(1 + r/100)^{t-1}}$$

Where,

$B\,(1 + r/100)^{t-1}$ = Production for the progressive year at (t)

A_t = Amount remaining at time t (years)

A_{t-1} = the initial reserve value

B = Fixed amount (production) taken at time interval t (yrs)

r = growth rate (2, 3, and 4 percent per year)

t = time elapsed in years.

From the equation, the various values of $[B\,(1 + r/100)^{t-1}]$ at each successive year, will be the forecast production value for that year at time (t); for various production and different assumed growth rate of 2, 3, and 4 percent per year.

The heuristic forecasting model

By definition, "heuristic" denotes a method of solving a problem for which no algorithm exists. It involves trial and error, as in iteration. In this discussion, heuristic knowledge indicates "soft," "qualitative," or "judgmental" knowledge. Although judgmental knowledge is lacking in the Numeric model, it is crucial for oil forecasting in the heuristic model "SCENERIOS". The model provides the user with a powerful interface for oil forecasting

The scenarios is based on EIA, 2000 methodology on how to forecast the possible year of peak, which is based on production growth rate of 2, 3, and 4 percent per year, and a decline reserve – to – production (R/P) ratio of 10. We find this method used by EIA, 2000, quite applicable and was adopted for use in this work.

Reserve – to – production (R/P) ratio

The relationship between the reserve and production levels, expressed as the ratio of reserve to production (R/P ratio) is often used in analysis for a mature producing area, the R/P ratio tends to be reasonably stable, so that the proved reserves at the end of the year serve as a guild to the production level that can be maintained during the following year.

R/P value may vary depending on the following;

- Geology
- Economies

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- Number and size of new discoveries
- Amount of drilling that has occurred
- Categories of Operators.

R/P ratios are indication of the state of development in an area and, overtime, the ratio change. Increase in production led to a decrease in R/P ratio. Table 2 shows the R/P ratio while Figure 4 shows the R/P Trend for Nigerian oil between 1980 – 2005.

Table 2: Total Production (Mbbl), Cumulative Reserve (Mbbl) and R/P Ratio

YEAR	TOTAL PROD.	RESERVE	Cal. R/P RATIO
1980	760117719	16400000000	21.57560545
1981	525291091	16450000000	31.31596991
1982	470638382	16550000000	35.16500276
1983	450961236	16550000000	36.69938496
1984	507487006	16550000000	32.61167243
1985	547088659	16600000000	30.34243121
1986	535929000	16066000000	29.97785154
1987	428886000	15980000000	37.25931833
1988	529007000	16000000000	30.24534647
1989	626651000	16000000000	25.53255321
1990	658791000	17100000000	25.95663875
1991	690982000	20000000000	28.94431403
1992	714220000	20991000000	29.39010389
1993	751380000	20991000000	27.93659666
1994	732798000	20991000000	28.64500176
1995	743927000	20828000000	27.99737071
1996	822095037	20828000000	25.33527033
1997	860879109	20828000000	24.1938732
1998	792435834	22500000000	28.39346611
1999	775799173	29000000000	37.38080809
2000	846636622	29000000000	34.25318401
2001	863107955	30000000000	34.75810856
2002	744988192	32000000000	42.95370094

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2003	836300764	32000000000	38.26374598
2004	863601672	33000000000	38.21206126
2005	886543980	33000000000	37.22319566

(Modified after OPEC, 2003)

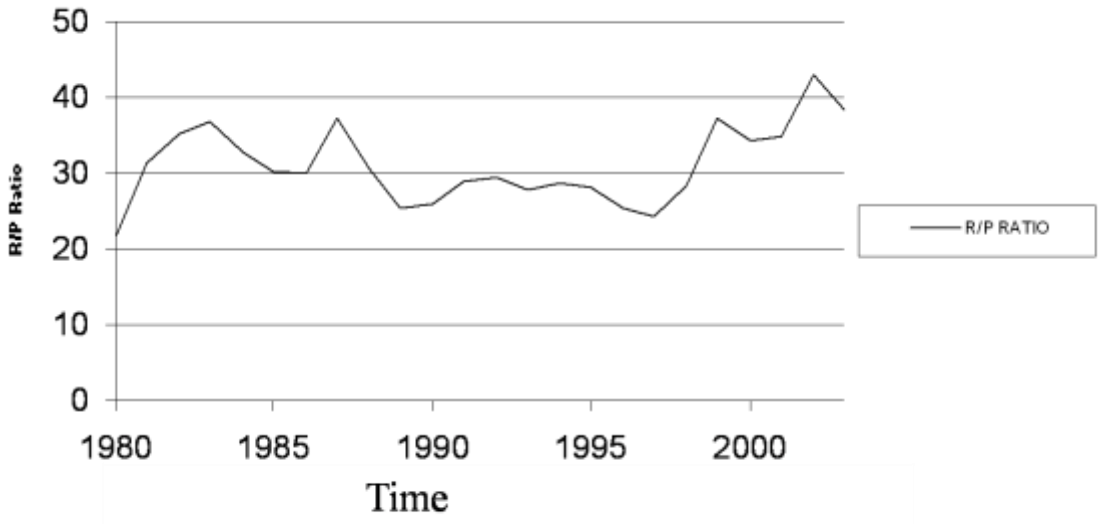

Figure 4: Reserve to Production R/P Ratio (1980-2005)

Results and discussion

Estimation of year of peak production

To illustrate the effect of production on forecast: based on the Nigerian reserve estimate of 33 billion barrels of crude (World Oil, 2005). We now use the EIA, (2000) methodology of simple long-term production rates scenarios designed to bracket the range of the future production outcomes. The scenarios were based on probable resource estimate (24, 32, and 40 billion barrels) of crude reserve, and three (3) annual production growth rates (2, 3, and 4 percent). Each scenarios addressed the question of when the peak would occur for a given resource base and production growth rate.

A key assumption in estimating the production year is the shape of the production curve after the peak is reached (determine by the decline rate). The Figure (5 to 8): shows what happens, if production both grows and decline at the rate of 2, 3, and 4 percent per year, until the 33 billion barrels mean resource estimate is recovered.

It is unlikely that any single constant growth or decline rate would persist before or after the year of peak production. Nigerian oil production has sometimes increased very rapidly in the past (e.g. 7.2 percent from 1984-85 and over 8 percent from 1998-2000). Production has sometimes decreased due to some factors like strikes and civil war in the Country. But in the recent time, growth rate has been slightly above 3 %

Annual Production Scenarios With 3 Percent Growth Rate and Decline Rates [(R/P) Ratio = 10]

In Figure 5, the line curve reflects the (EIA methodology) in which Nigerian oil production may be assumed to grow at a rate of 3 percent per year, until the ratio of reserve to annual production (R/P) declines to 10. At that point (the peak), Nigerian production is assumed to begin to decline in a way to maintain a constant (R/P) ratio.

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The reason for setting the decline at R/P ratio of 10 is that, at R/P ratio of 10, the field is assumed to be matured at this ratio, also because of the Texas (US) experience (EIA, 2000). The Texas (US) is a very mature producing Country with a production history of over 100 years, and has had R/P ratio between 8 and 10 for the past 50 years. The R/P ratio was 12 in the 1940's and 1950's and dropped below 10 in the 1990's.

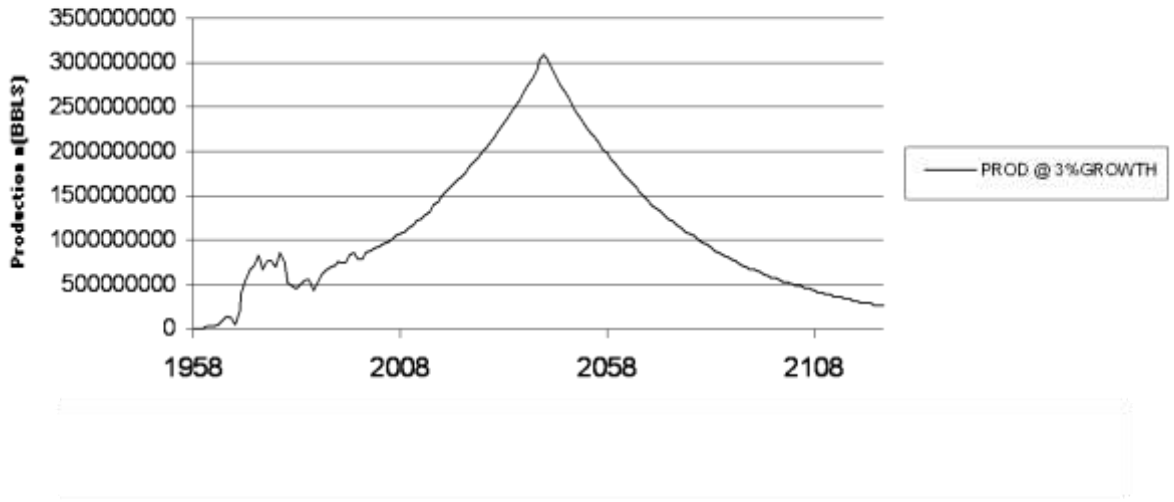

Figure 5: Annual Production Scenario for 3 Percent Growth Rate (Decline Rate R/P=10)

Annual Production Scenarios at Different Resource Levels [Decline (R/P) = 10]

The timing of the estimated production peak or the forecast year of peak production is relatively sensitive to variation in the resource base estimate; the higher the increase in the amount of reserve, the further away, is the expected year of peak and vice versa.

If the reserve is increase significantly, say an addition of about 8 billion barrels to the mean resource of 32 billion barrels. This addition will delay the estimated peak, if we assumed production growth rate of 3 and decline of R/P of 10, the expected year of peak will delay or shift forward by another seven (7) years along the production curve to new year of peak 2050 (Figure 6). Similarly, subtracting 8 billion barrels from the mean resource base of 32 billion barrels and with assumed production growth rate of 3 percent per year will bring the estimated production peak by ten (10) years earlier than expected, along the production curve to a new year of peak 2033.

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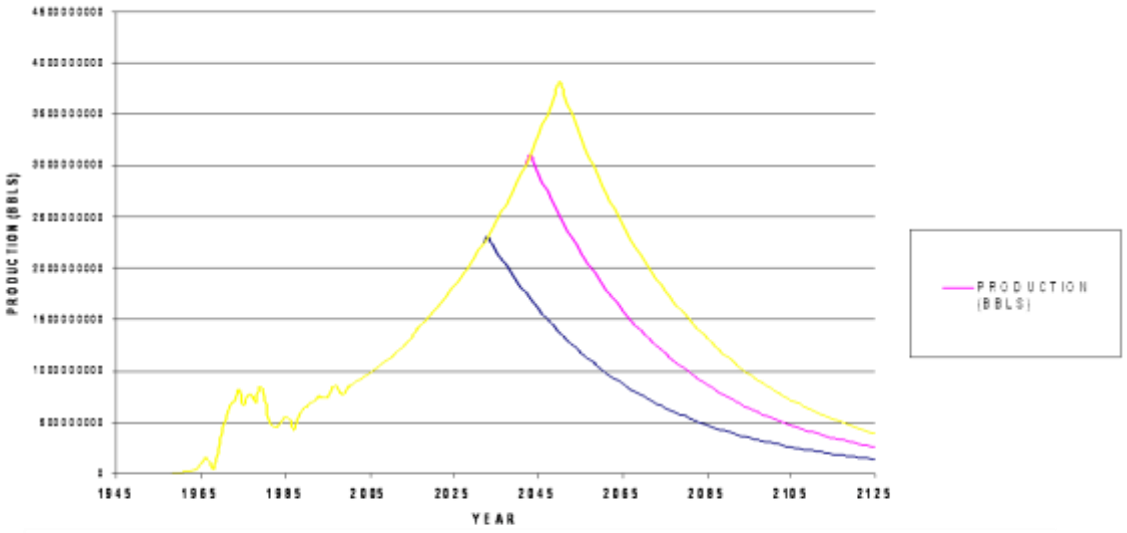

Figure 6: Annual Production Scenario for 3 Percent Growth Rate and Different Resource Levels (Decline Rate R/P=10)

Annual Production Scenarios for the Mean Resource Estimate at Different Growth Rate [Decline (R/P) =10]

A change in production growth rate per year will ultimately alter the forecast year of peak. A decrease of one (1) percent growth rate from (3 to 2) percent per year, will delay the estimated peak production year by twenty two (22) years. While a growth rate increase of one (1) percent per year from (3 to 4) will accelerates the production peak by ten (10) years (Figure 7).

From the figure 7, the three (3) curves show that:

1) At 3 percent per year growth rate and decline of R/P = 10, the peak production year will be 2043,
2) At 2 percent per year growth rate and decline of R/P = 10, the peak production year will be 2065, twenty two (22)years later, and
3) At 4 percent per year growth rate and decline of R/P = 10, the peak production year will be2033, ten (10) years earlier than forecast.

We therefore estimate or forecast a range of time for Nigerian peak of production base on (2, 3, and 4) percent growth and decline of (R/P) of 10 to be between the year 2033 and 2065 (a span of 32 years) as a range of production peak.

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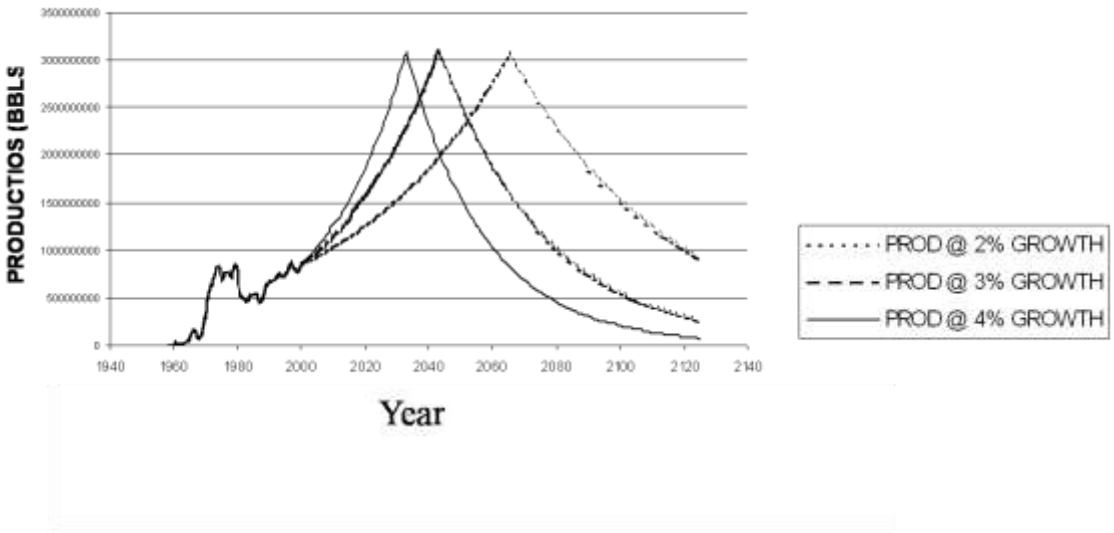

Figure 7: Annual Production Scenerios at Different Growth Rate (Decline Rate R/P=10)

Summary

Five (5) Nigerian conventional oil production scenarios

Figure 8 shows summary graphs for all long-term production scenarios based on the three (3) annual production growth rate (2, 3, and 4) percent per year, and the three (3) technically recoverable oil resources volumes (24, 32, and 40) of Oil and Gas Journals, 2002, World Oil, 2003, and Petro consults (Tuttle, et al, 2003) estimates respectively.

The estimated peak year of production range from 2033 to 2065 (a span of 32 years) for the 2, 3, and 4 percent per year growth rates and three (3) resource volume.

For the mean resource and three (3) percent production growth rate "SCENARIOS" which reflect the expected resource volume and the recently experienced production growth rate, the peak occurs at 2043.

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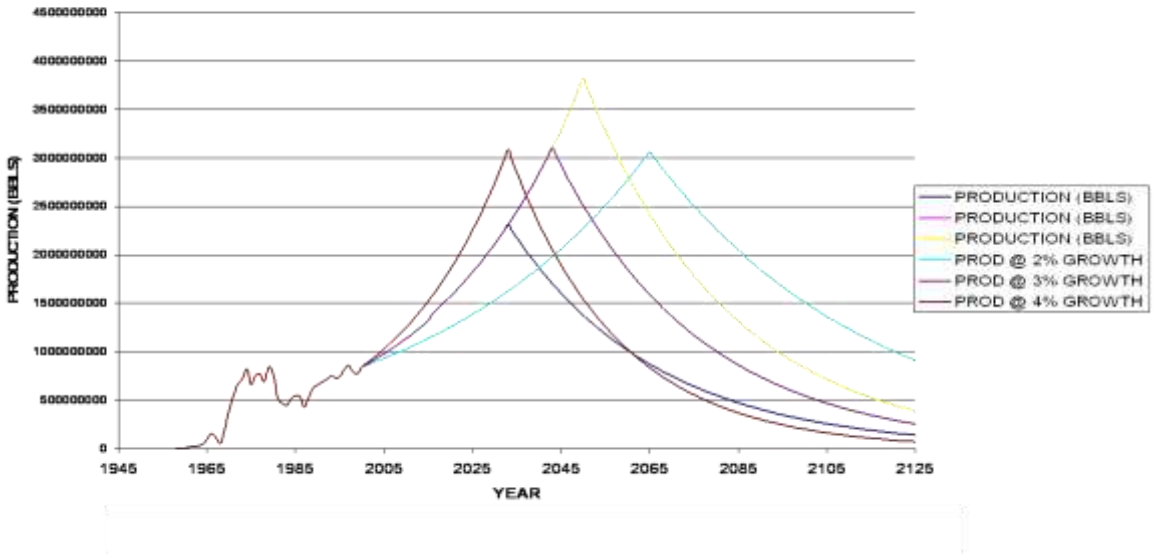

Figure 8: Five (5) Nigerians Conventional Oil Production Scenarios (Summary)

Factors that may affect the year of peak production

1. The peak year would be delayed by discovery of large recoverable conventional resource base, than is currently estimated, or it could occur earlier with accelerated production rates.
2. The peak may also be delayed as a result of global variation in oil demand, for example, if the demand for oil reduces for economic reasons, or because of substitutes for conventional oil gains market share, the conventional oil production growth rate may decline and result in a latter peak, later than the forecast year.
3. If OPEC decides to cut the production quota for Nigeria as a result of various measures. This may result in a later peak. On the other hand, if the production quota is also increase, by OPEC, the production peak will be realized earlier than the projected year.
4. Advance in new technology, may lead to new discovery and subsequently lead to an increase in reserve. This will shift the year of peak forward.

Conclusion

In general, we have not relied so much on reserve estimates in our forecast, as we believe these to be less reliable than the actual production figures. Reserve estimates are subject to political and economic factors. Basing production forecast on reserve estimates, as is done by the OPEC nations, may cause reserve to be overstated (Duncan and Youngquist, 1999).

Although, production figures are subject to some error or deliberate misstatement, we believe that production figures can be verified more easily than reserve (unseen oil in the ground). In addition, production generally represents the true ability of oil fields to produce, except in instances where production may from time to time be restrained artificially (e.g. OPEC quotas). For this reason, the major parts of our nation oil forecasting is based chiefly on production history, which also was the basis of Hubbert's successful 1956 forecast of the Texas (US) 1970 oil peak forecast.

We have used a special method, termed a "SCENARIOS" to track our progress (based on EIA methodology) in establishing the peak. Each forecast pinpoints a milestone along the route. The first forecast (Scenarios) using two (2) percent growth rate and a decline R/P =10, put the peak to be 2065; the second forecast "Scenarios" using three (3) percent growth rate and decline R/P = 10, put the peak in 2043. The third forecast "Scenarios" using four (4) percent growth rate and decline R/P ratio = 10, put the peak year to be 2033. By taking the average of the three successive peaks, we now encircle closer to the peak of Nigeria oil production.

However, the exact date will not be known for certain, until sometime after that year arrives, when it can be viewed, in retrospect with the downward trend, well established. The peak may be more evident by a sharp rise price as demand begins to exceed supply at high price levels (Duncan and Youngquist, 1999).

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The important point to note in this work is that, by all reasonable estimates, the peak of Nigerian oil production may be reached within the lifetime of most people living today, in the shortest distance. In addition, the implication of the peak of Nigerian oil production, and the beginning of the irreversible decline (finite) in oil supplies, cannot be overstated. It is important to note that, (Duncan and Youngquist, 1999) oil discovery rate peaked in the early 1960's and that about 80 percent of the oil produced in the World today (including Nigeria) flows from fields that found before 1973, and the great majority of them are declining.

According to Youngquist (1999), "Policy makers Worldwide must face the reality of soon beginning to move into a post-petroleum economy, which will be markedly different from our present circumstances.

Our case (Nigeria) must not be different, we must begin to face the reality now and ask ourselves the question, where do we go from here? We should be concerned and stand-up for it now.

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