Aeon Petroleum Consultants
Quarterly Newsletter

Aeon Petroleum Consultants is a professional engineering firm registered in the State of Texas. We specialize in estimating resources and reserves. Our intent on publishing this newsletter is to highlight topics of interest to those involved in estimating, reviewing, or reporting oil and gas resources and reserves.

In this first issue, we will discuss the following:

- Aeon Petroleum Consultants website
  - New items on our website
- Petroleum Economics
  - Economic modelling
  - Software to use for economics available from Aeon Petroleum Consultants
- Curtailed production
  - Why some production is curtailed
  - How to calculate curtailment production volume and time

We hope to make this quarterly newsletter informative and useful. If there are any topics you would like us to discuss in future newsletters, please contact us on our website and let us know.

Aeon Petroleum Consultants Website

The website for Aeon Petroleum Consultants can be found at:

www.aeon-petro.com

The website contains topics and items that should be of interest to those estimating, reviewing or reporting oil and gas resources and reserves. Besides listing the services that Aeon Petroleum Consultants can provide to the oil and gas industry, there are items available for download, software created by Aeon Petroleum Consultants available for download or demo, videos, and resource and reserve guidelines for viewing and download.

The book *Elements of Petroleum Reservoirs* is now in the public domain. We have had this book scanned into pdf format and made available for free download.

Downloads and demos are available here:

https://aeon-petro.com/supplement/shop/

Please feel free to contact us regarding our services, software, or items you would like us to discuss in these newsletters.

Petroleum Economics

As reserve estimators, we have a great deal of experience modelling petroleum projects. These projects can include oil and gas wells, gathering systems, pipelines, and gas plants. Most projects follow a similar pattern of:

- Initial capital cost
- Project start-up
- Period of revenues, expenses, and capital costs
- End of project
- Capital cost for abandonment and remediation

Shown graphically below is an oil well project showing pertinent time periods and economic parameters:

Oil Well Project
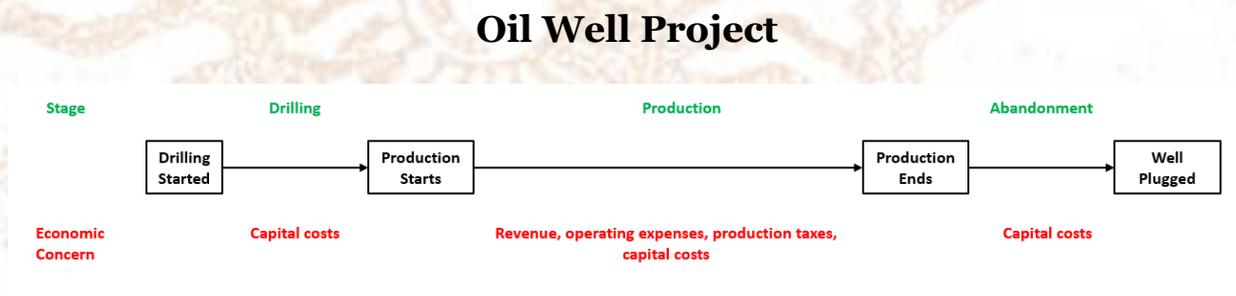
Creating a drawing like this is especially useful when dealing with complex economic models. The economic modelling of this project would involve estimating the drilling and completion costs, forecasting oil (and possibly gas and NGLs), estimating operating expenses and periodic capital costs, and estimating a capital cost for the abandonment and remediation of the well site.

For the economic modelling of oil and gas wells there are several commercial software products available to the modeler. These programs are typically expensive, require training to use properly, and have a lot of features that are seldom used. For large operating companies or consultancies, these costs can be amortized over the number of wells or clients. For smaller companies, however, these costs can be burdensome and not worth the price. Due to the number of calculations involved, oil and gas well economics are very time-consuming to perform.

The principals of Aeon Petroleum Consultants have performed economic modelling on oil and gas wells for over 40 years. During that time period we have used many different economic modelling programs. That experience has taught us which features of those programs are used often and which are seldom used.

This year we decided to write our own Excel-based economics software. The initial version of software has been created. This version is titled "Aeon Basic 20 Petroleum Economics" and is a basic version that has the following features:

- Maximum of 20 wells
- Forecast oil, gas, and NGLs
- Individually forecast oil and gas, or use ratios
- Ability to forecast hyperbolic/harmonic to exponential decline
- 30+ year price deck
- No escalations of operating expenses
- Fixed and variable operating expenses for all products
- Production taxes as % of revenue or $ per unit on all products
- Summaries and one-line listings by reserve category
- Monthly output of gross forecasts for each well on a separate spreadsheet
- One-line ranking of value

Please watch the upcoming video and download a demo for a try. Here is the link:

https://aeon-petro.com/supplement/shop/

A second economics software program is completed and the operating manual being written. This version is a freeform model with multiple templates than can be chosen and duplicated within the workbook. This economics model will allow for escalations of operating expenses, forecasts of curtailment, and multiple capital costs. The various templates will allow direct forecasting, cut-and-paste of monthly production, cut-and-paste of

annual production (great for due diligence), and the creation of summaries. Stay in touch as this will be available during the third quarter of 2021.

Production Curtailment

In past years, the curtailment of production used to be quite common. Most production curtailment at that time was due to state law regarding equitable withdrawals from reservoirs of agreements between offset operators to prevent loss of reserves. At the present time, curtailment of production is not prevalent except in special cases. One case is when production is processed through a gas plant that limits production based on plant design. The production of wells completed in helium-bearing and CO_2-bearing reservoirs are almost always curtailed due to plant limitations. Oil production can be limited due to pumps or gathering systems as in the case of offshore facilities.

When using decline curves to estimate future production, one of the limitations for decline curve use is that wells should be producing at their maximum rate based on choke configuration. So, how can we estimate the amount of time a well will be on curtailment?

Let's start by assuming we would like to know the time of curtailment to the nearest month. To make it easier to calculate, we will use monthly decline rates and monthly production volumes so we won't have to do any time unit conversions. Although curtailment can be applied to any type of well decline, we will show an example of a well declining exponentially. The equation for exponential decline is:

$$q_m = q_{im} * (1 - d_m)^t$$

where,
      q_m = monthly rate at time t (bbl/m or Mcf/m)
      q_{im} = initial monthly rate (bbl/m or Mcf/m)
      d_m = monthly decline rate (decimal per month)
      t = time (months)

In the case where q is known in daily rates and d is known in annual decline (which is the most common case), these can be converted to monthly rates as:

$$q_m = \frac{365}{12} * q_d$$

$$d_m = 1 - \left(1 - d_y\right)^{\frac{1}{12}}$$

where,

q_m = monthly rate (bbl/m or Mcf/m)
q_d = daily rate (bbl/d or Mcf/d)
d_m = monthly decline rate (decimal per month)
d_y = annual decline rate (decimal per year)

The exponential decline equation above assumes the well is producing at a maximum rate and cannot be used for curtailed situations. We can, however, solve for the cumulative production produced between two rates if we know the current producing rate, curtailed rate, and decline rate. The cumulative volume produced between two rates is:

$$N_p = \frac{q_m - q_{cm}}{-\ln\left(1 - d_m\right)}$$

where,

N_p = cumulative production (bbl or Mcf)
q_m = current monthly rate (bbl/m or Mcf/m)
q_{cm} = curtailed monthly rate (bbl/m or Mcf/m)
d_m = monthly decline rate (decimal per month)

Now that we have the cumulative production to the curtailment rate, the time is calculated as:

$$t = \frac{N_p}{q_{cm}}$$

From that time onward, the well will be back on exponential decline. For cases of hyperbolic or harmonic decline, the table below gives equations for calculating rates and cumulative production.

Decline Curve Types and Equations

Decline Type	Rate Time	Cumulative Volume
Exponential	$q = q_i * (1 - d)^t$	$N_p = \dfrac{(q_i - q)}{-\ln(1-d)}$
Hyperbolic	$q = \dfrac{q_i}{(1 + b * d_i * t)^{\frac{1}{b}}}$	$N_p = \dfrac{q_i{}^b}{d_i * (1-b)} * (q_i^{(1-b)} - q^{(1-b)})$
Harmonic	$q = \dfrac{q_i}{(1 + d_i * t)}$	$N_p = \dfrac{q_i}{d_i} * \ln\left(\dfrac{q_i}{q}\right)$

For the above equations, make sure all decline rates and times are monthly. The decline rate d$_i$ for use in hyperbolic and harmonic equations must be calculated from the effective decline rate. The effective decline rate is the exponential instantaneous decline rate. To calculate the hyperbolic decline rate (also used for harmonic decline), use the following equation:

$$d_i = -\ln(1 - d_e)$$

where,

d_i = hyperbolic/harmonic decline rate (decimal per month)
d_e = exponential decline rate (decimal per month)