Profile Help

Profile

Production Profile Generation and Analysis

by Petroleum Solutions Ltd

Profile Help

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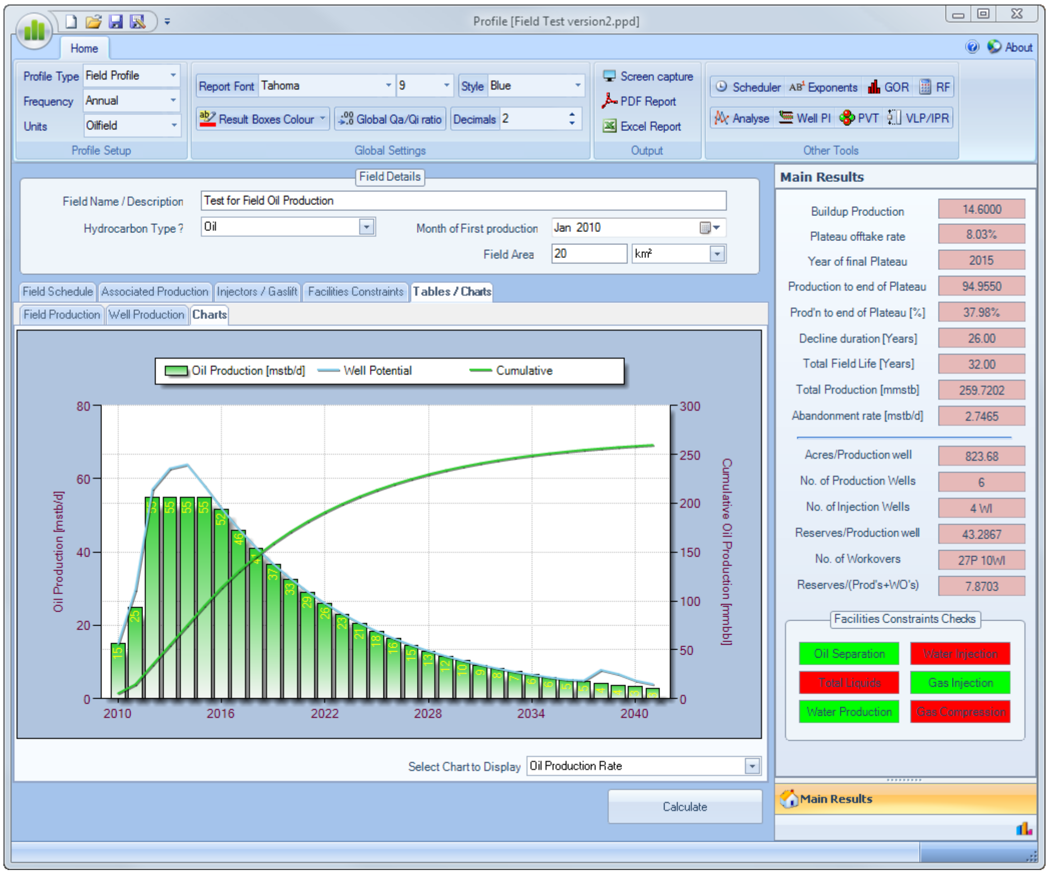
Part I

1 Welcome to Profile

1.1 Introduction



Profile is an easy to use application intended for Petroleum Reservoir Engineers to :

- Quickly prepare and analyse primary and associated production profiles.
- Compare to analogue fields for well spacing, recovery/well, plateau offtake rates, decline rates,
- Quicklook sizing for facilities throughput capacity for all production and injection streams.

The assumptions behind ***Profile*** are based on the various phases of production life of an oil or gas field, ie,. a buildup period, a plateau period and a decline period.

Two different approaches for generating primary hydrocarbon phase production profiles are provided within this application.

Either :

- The ability to generate a field production profile by defining the field production buildup, plateau and decline rates and recoverable reserves. The application solves for the required number of development wells; producers and injectors, that fit with the timing of the field production profile, or

- The ability to generate a field production profile by specifying different well types and the schedule for drilling these wells. This approach permits the modelling of different well recoveries and workovers, etc. The field profile is simply the sum of all the wells specified in the well schedule

The ability to quickly model associated hydrocarbon phases (either gas for an oilfield or condensate for a gas field), and water production for an oilfield is provided, together with the ability to quickly model water injection, gas injection, requirements for gas fuel and flare and schedule workovers.

License.dat File

The "License.dat" file is located in the Application Startup folder (eg C:\Program Files\Petroleum Solutions\Profile\)

The contents of this ASCII license file needs to contain the following license information.

[License Settings]
LicensedTO =
Company =
ProductID =
LicenseID =

If any of the above License key information is incorrect or absent, or if the License.dat file is missing then the application will fail to startup.

.NET Framework

This application requires the presence or installation of Microsoft .Net Framework version 2.

.NET Framework version 2 is a component of the Microsoft Windows® operating system used to build and run Windows-based applications.

Should .NET Framework version 2 not be installed on the destination PC then a link is provided below to download this system software. The user should download and install .NET Framework version 2 before attempting to install this application.

http://www.petroleumsolutions.co.uk/downloads.html

The installation of .Net Framework also requires a minimum software and hardware requirement. Details of which are shown below. Specifically, note that you cannot install the .NET Framework on a computer running the Microsoft Windows 95 operating system.

Minimum requirements

To install .NET Framework [Dotnetfx.exe], you must have one of the following operating systems, with Microsoft Internet Explorer 5.01 or later installed on your computer:

- Microsoft® Windows® 98

- Microsoft® Windows® 98 Second Edition
- Microsoft® Windows® Millennium Edition (Windows Me)
- Microsoft® Windows NT® 4 (Workstation or Server) with Service Pack 6a
- Microsoft® Windows® 2000 (Professional, Server, or Advanced Server) with the latest Windows service pack and critical updates available from the Microsoft Security Web site (www.microsoft.com/security).
- Microsoft® Windows® XP (Home or Professional)

Recommended hardware

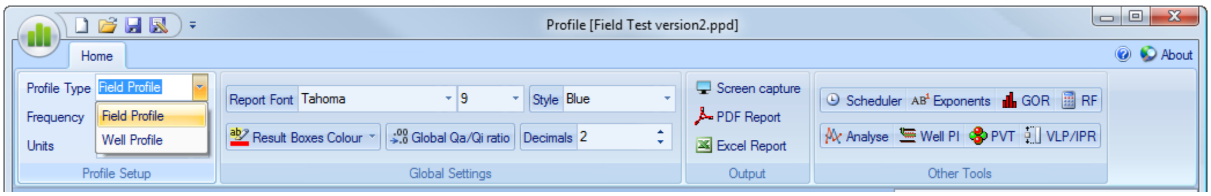
CPU Recommended	RAM Recommended
Pentium 90 MHz or faster	96 MB or higher

Part II

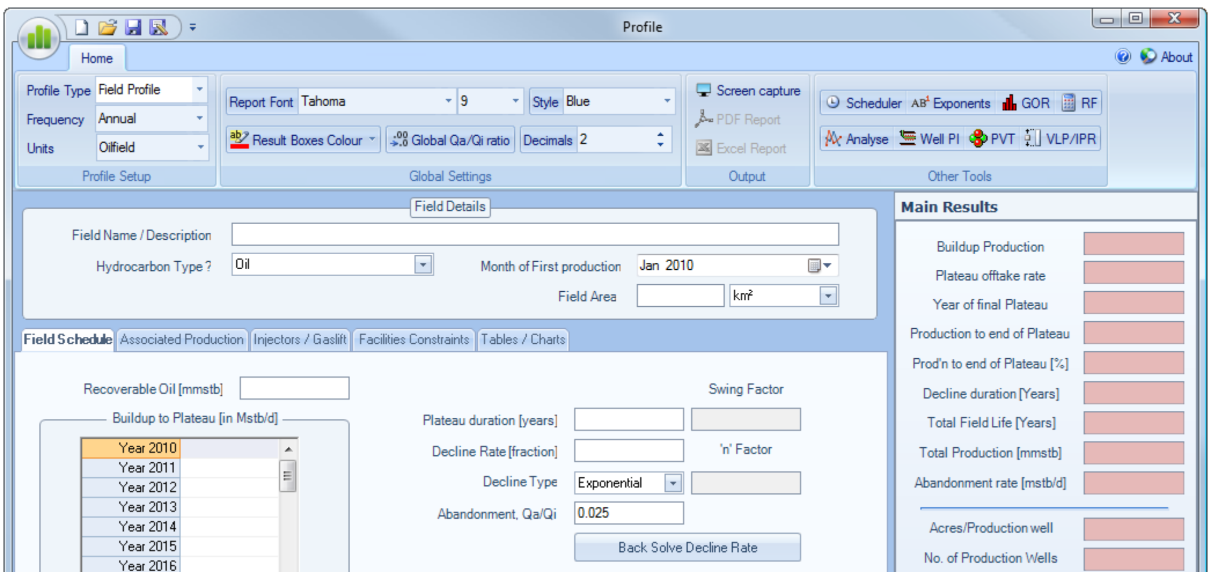
2 Field Schedule

2.1 Defining Field Input

The user can choose between working with a ***Field Profile*** approach or a ***Well Profile*** approach by choosing the dropdown box in the main toolbar menu, as shown below.



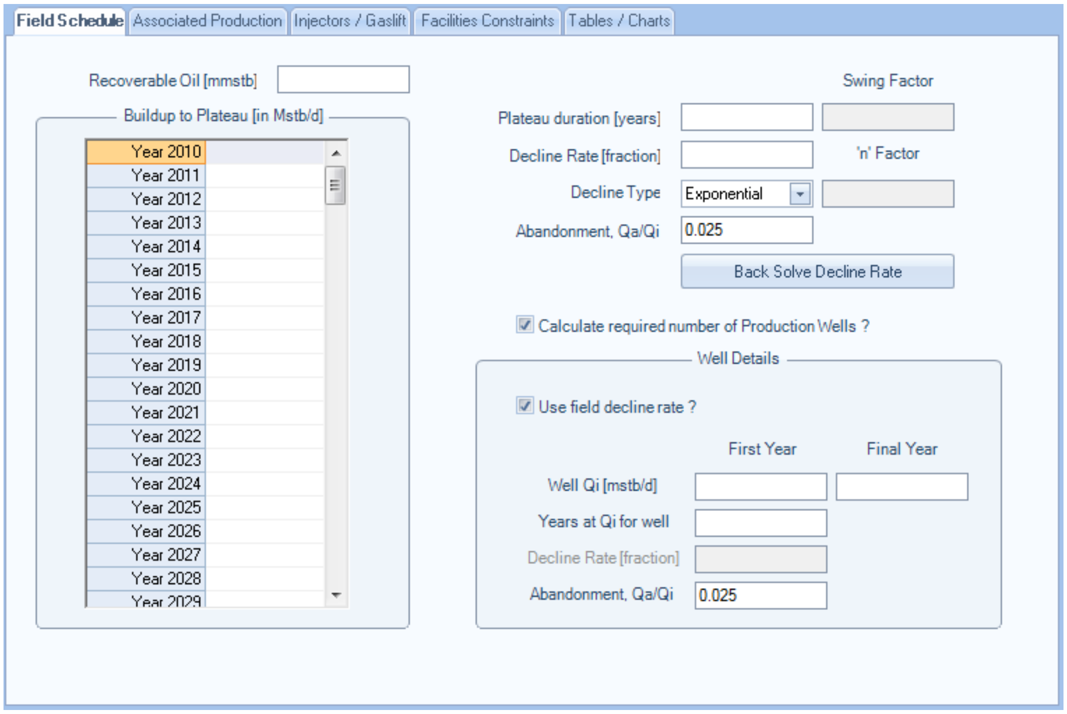
Once the ***Field Profile*** approach is chosen the application main tab bar should change to the following.



Under the same main toolbar menu, the user can also select between ***Oilfield Units*** and ***Metric Units***, which determines the units preference applied throughout all the panels and forms within the application.

Again under the same main toolbar menu, the user can also choose between ***Annual*** or ***Semi-Annual*** or ***Monthly*** periods for reporting purposes. All internal calculations are done on a monthly basis and reported in Annual, Semi-Annual or Monthly periods.

Once the user selects the Field Profile approach and selects the Field Schedule button in the main toolbar the following Main Panel should become visible.



The User should attempt to type in as much data as possible.

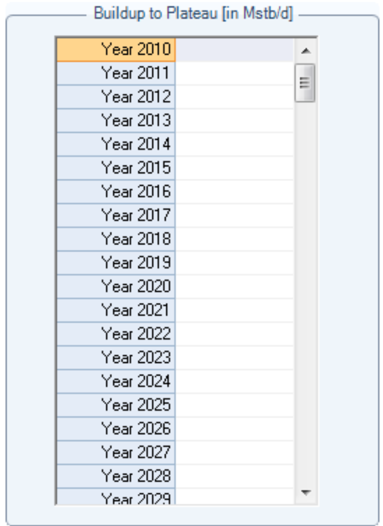
A Fieldname / Description [OPTIONAL] is only used for reporting purposes.

The Hydocarbon Type [REQUIRED] determines the primary & secondary hydrocarbon phases, and also determines the applicability of water production and water injection.

First Month of production [REQUIRED] is the month in which first oil or gas production is achieved. Once a month has been input and validated for errors the labels will change to reflect the actual years or months in the Buildup to plateau panel. See below.

The Field Area [OPTIONAL] is used to determine the Area / Production Well calculated and displayed in the Main Results Panel located on the right of the main application screen.

Recoverable Oil (or Gas) [REQUIRED] is the target ultimate recovery for the field or prospect being analysed.



Buildup to Plateau [REQUIRED] is the primary hydrocarbon phase production rates building up to a final rate, which is assumed to be the plateau production rate.

Plateau duration [REQUIRED] is simply the number of years that the field remains on it's plateau production.

Swing Factor [OPTIONAL] is a well deliverability check provided for gas fields that operate on a summer/ winter swing basis. ie if a number of 1.25 is entered, then the application will check that the well deliverability can achieve 1.25 x the field production levels, otherwise the application will add additional wells to ensure that this deliverability can be met.

Decline Type [REQUIRED]. The user is given the option of either exponential or hyperbolic decline type

The exponential decline curve, or constant rate decline [since the decline rate does not change with time], equation is shown below.

$$q = q_i e^{-at}$$

Where,

- q = Production rate at time = t
- qi = Initial production rate
- a = Constant decline rate fraction, between 0 and 1
- t = time, typically measured in months or years.

The hyperbolic decline curve equation is shown below.

$$q = q_i (1 + n a_i t)^{-1/n}$$

Where,

- n = additional constant decline exponent, between 0 and 1

Special cases for the hyperbolic decline equation occur at n=0 [exponential decline] and n=1 [harmonic decline].

The following text is taken from "Petroleum Engineering Handbook" published by the Society of Petroleum Engineers, page 40-26.

"An analysis of a large number of actual production-decline curves assembled by Cutler indicates that most decline curves normally encountered are of the hyperbolic type, with values for the exponent n between 0 and 0.7, while the majority fall between 0 and 0.4."

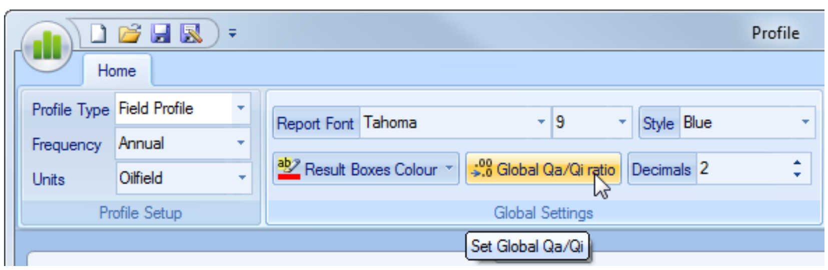
Decline Rate [REQUIRED] is the constant decline rate fraction, between 0 and 1, in the exponential [a] or hyperbolic [a_i] decline equation.

'n' Factor [REQUIRED if decline type = Hyperbolic] is the additional constant decline exponent, between 0 and 1, in the hyperbolic decline equation.

A simple tool is provided via the main menu item 'Tools\Backcalculate Decline Exponents' to quickly calculate values for decline rate parameters 'a' and 'n'. See help topic Backcalculate Decline Exponents.

Abandonment, Qa/Qi [REQUIRED] determines the year of field abandonment and is simply defined as the ratio of the final rate divided by the initial rate. Typical values are 0.1 or 0.05.

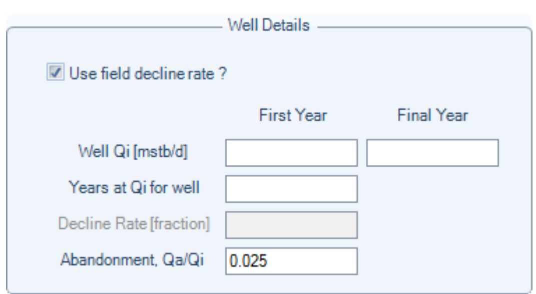
The Abandonment, Qa/Qi value is required in several places across the application, therefore the user can choose to select to change the global value by selecting the relevant inputbox, accessed via the menu option Options/Set Global Qa/Qi, shown below.



Back Solve Decline Rate button

Assuming the user has entered sufficient buildup rates, plateau duration and the target ultimate recovery, then the user can press the Back Solve Decline Rate button to quickly back calculate the appropriate decline rate to equal the target ultimate recovery.

Well Details panel



The above panel determines how to calculate the number of production wells required to meet the field production profile, assuming these have already been defined by the buildup, plateau and decline periods.

The user is provided with a simple method for modelling the potential for degrading well recoveries versus field life by entering different well rates for the first year and the final year. A simple linear interpolation is done between the first and final year well rates to determine an specific years well rate.

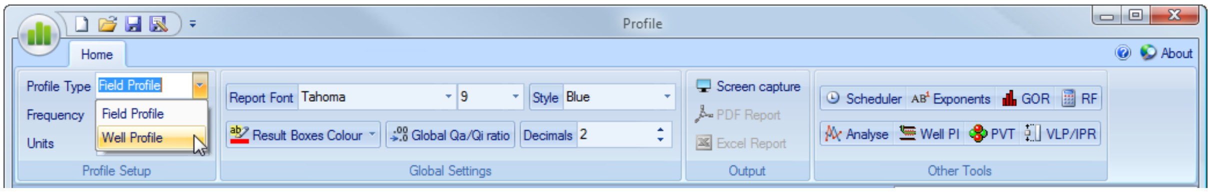
The user can also choose to un-check the Use field decline rate ? check box and enter a more or less aggressive well decline rate in comparison to the field decline rate.

Part III

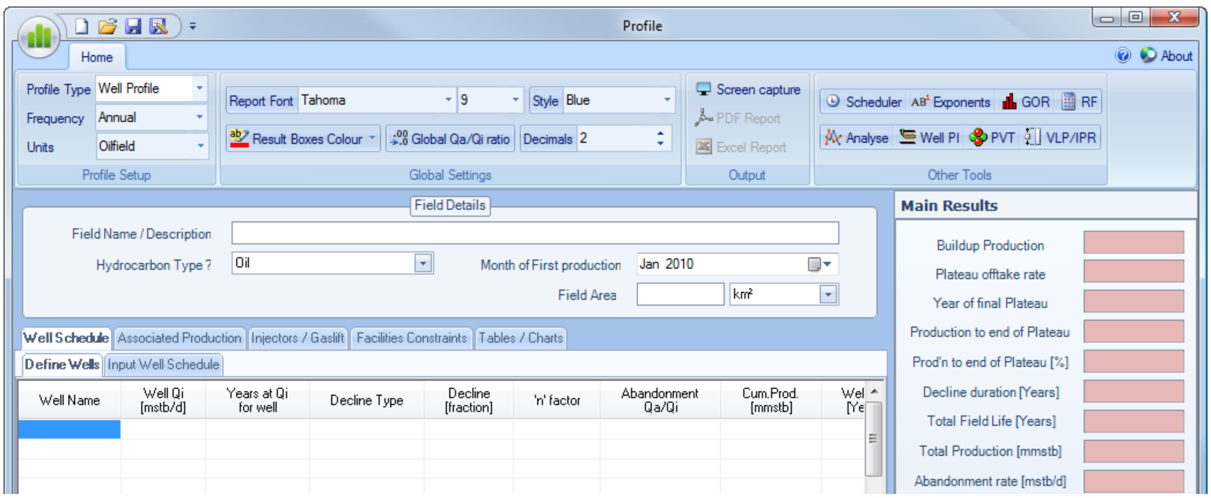
3 Well Schedule

3.1 Defining Wells

The user can choose between working with a ***Field Profile*** approach or a ***Well Profile*** approach by choosing the dropdown box in the main toolbar menu, as shown below.



Once the ***Well Profile*** approach is chosen the application main tab bar should change to the following.



Under the same main toolbar menu, the user can also select between ***Oilfield Units*** and ***Metric Units***, which determines the units preference applied throughout all the panels and forms within the application.

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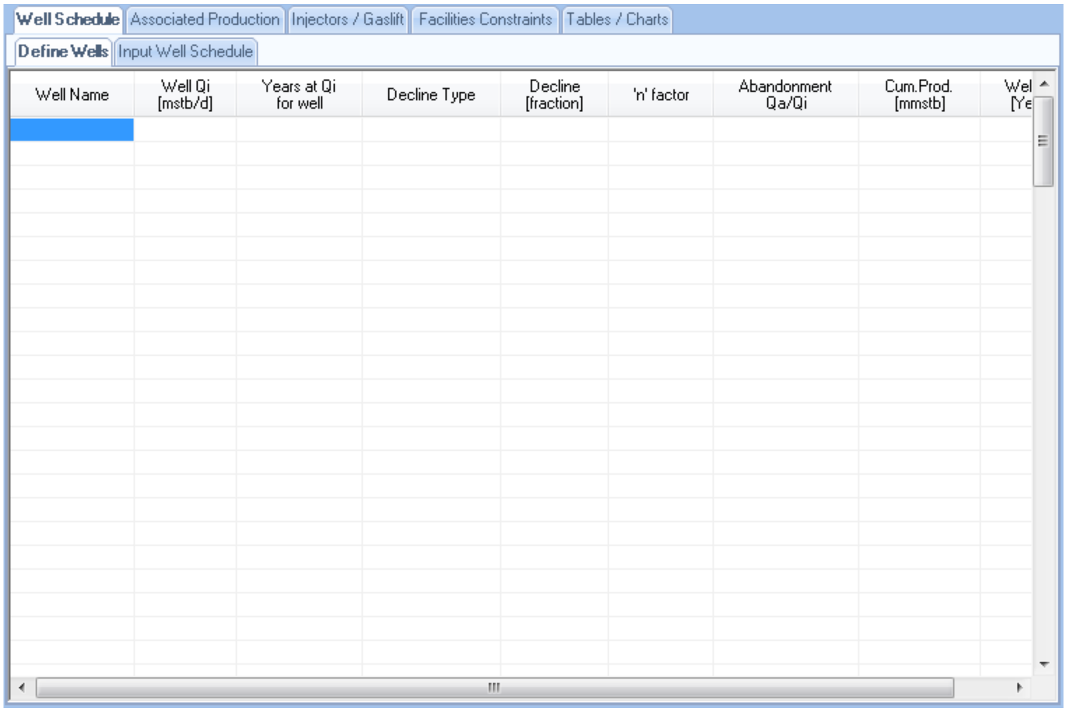
Once the user selects the Well Profile approach and selects the Well Schedule button in the main toolbar the following Main Panel should become visible.



The User should attempt to type in as much data as possible.

A Fieldname / Description [OPTIONAL] is only used for reporting purposes.

The Hydocarbon Type [REQUIRED] determines the primary & secondary hydrocarbon phases, and also determines the applicability of water production and water injection.

First Month of production [REQUIRED] is the month in which first oil or gas production is achieved. Once a month has been input and validated for errors the labels will change to reflect the actual years or months in the Buildup to plateau panel. See below.

The Field Area [OPTIONAL] is used to determine the Area / Production Well calculated and displayed in the Main Results Panel located on the right of the main application screen.

Well Name [REQUIRED] is a text string intended to briefly describe the type of well to be modelled, eg. Good, Medium, Poor, Long, Short, Horizontal, Vertical, etc.

Well Qi [REQUIRED] is the peak initial well rate

Years at Qi for well [REQUIRED] is the well plateau production period in years

Decline Type [REQUIRED] as with the ***Field Profile*** approach, the user is given the option of either exponential or hyperbolic decline type.

The exponential decline curve, or constant rate decline [since the decline rate does not change with time], equation is shown below.

$$q = q_i e^{-at}$$

Where,

- q = Production rate at time = t
- qi = Initial production rate
- a = Constant decline rate fraction, between 0 and 1
- t = time, typically measured in months or years.

The hyperbolic decline curve equation is shown below.

$$q = q_i(1+na_it)^{-1/n}$$

Where,

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Special cases for the hyperbolic decline equation occur at n=0 [exponential decline] and n=1 [harmonic decline].

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Decline Rate [REQUIRED] is the constant decline rate fraction, between 0 and 1, in the exponential [a] or hyperbolic [a_i] decline equation.

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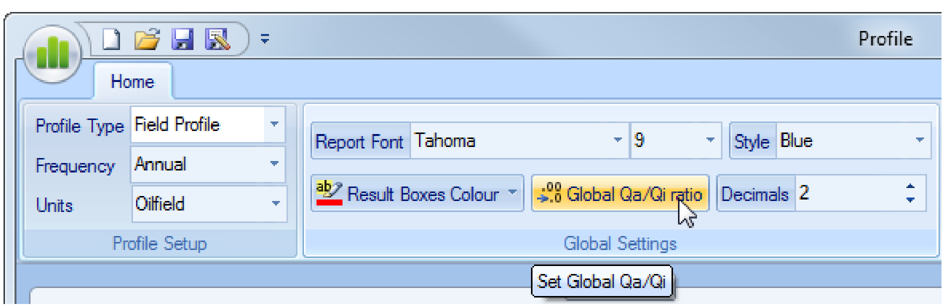
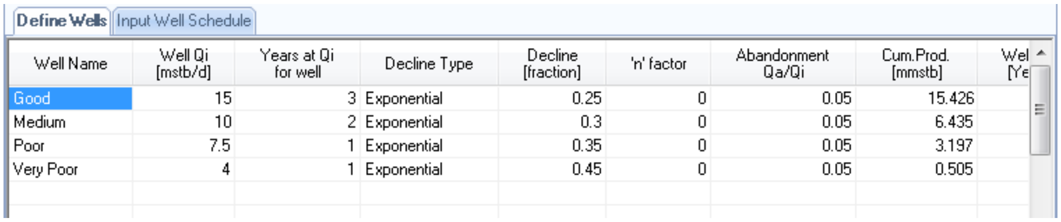


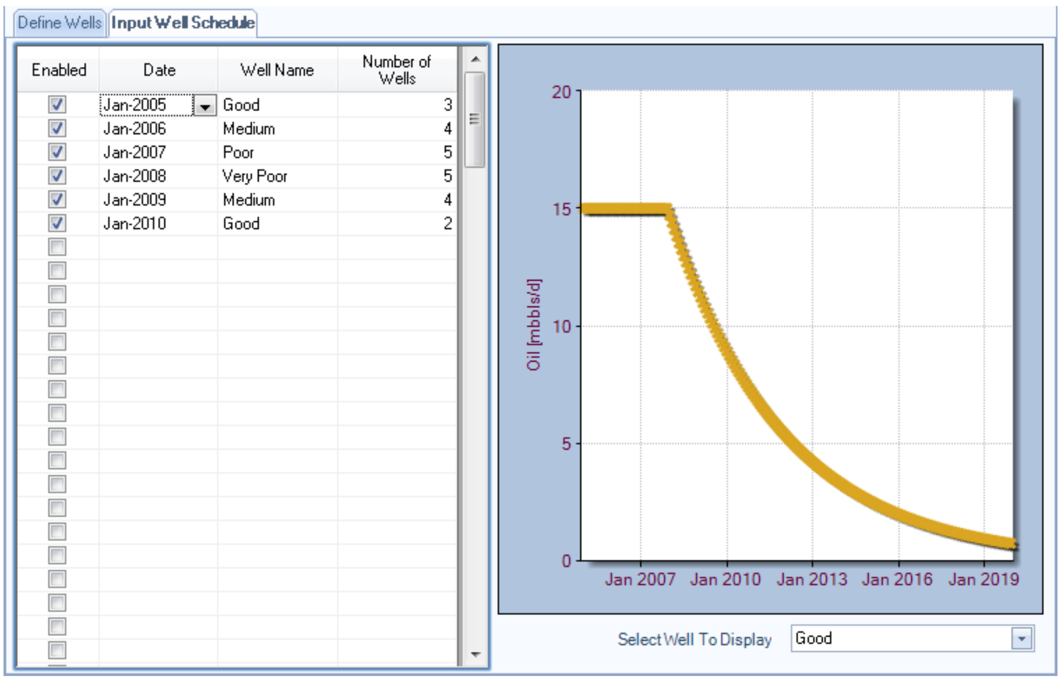
Once all of the above required data has been input for an individual well, then the application will automatically calculate the cumulative production and well life, as shown below.



Well Name	Well Qi [mstb/d]	Years at Qi for well	Decline Type	Decline [fraction]	'n' factor	Abandonment Qa/Qi	Cum.Prod. [mmstb]	Wel [Ye
Good	15	3	Exponential	0.25	0	0.05	15.426	
Medium	10	2	Exponential	0.3	0	0.05	6.435	
Poor	7.5	1	Exponential	0.35	0	0.05	3.197	
Very Poor	4	1	Exponential	0.45	0	0.05	0.505	

3.2 Defining Schedule

Once *Define Wells* has been complete then the user can select the second tab [*Input Well Schedule*] to commence scheduling of the predefined wells.



Both the *Date* and *Wellname* input boxes are populated based on the data entered on the previous tab *Define Wells*. The *Date* input boxes contain all the annual or semi-annual dates between the already defined start year and end year.

Check boxes are provided to the left of the *Date*, *Wellname* and *No.Wells* input boxes to quickly enable/ disable the row input in the profile calculation.

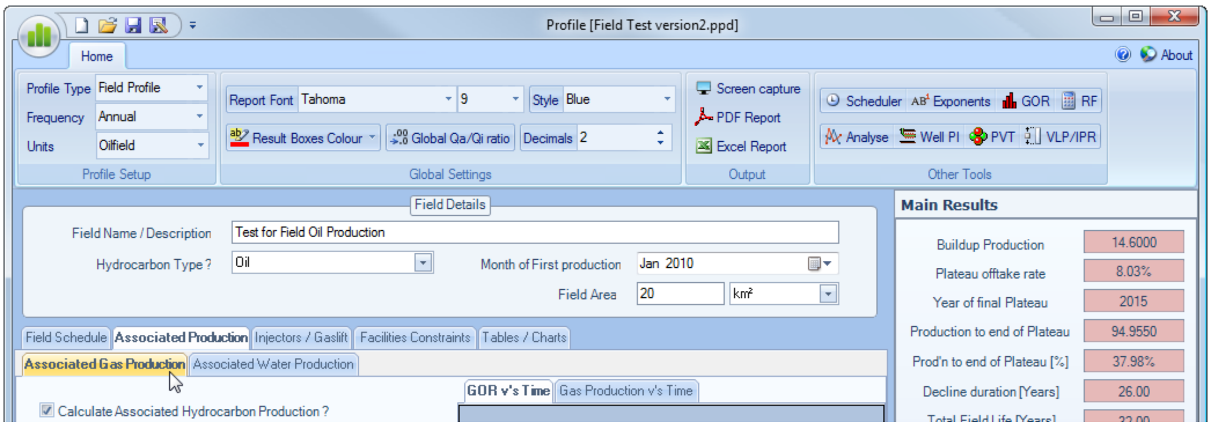
The user can display the individual well production profiles they defined in the Define Wells tab by selecting the drop down list box located at the bottom right hand corner of the *Input Well Schedule* tab

Part IV

4 Associated Production

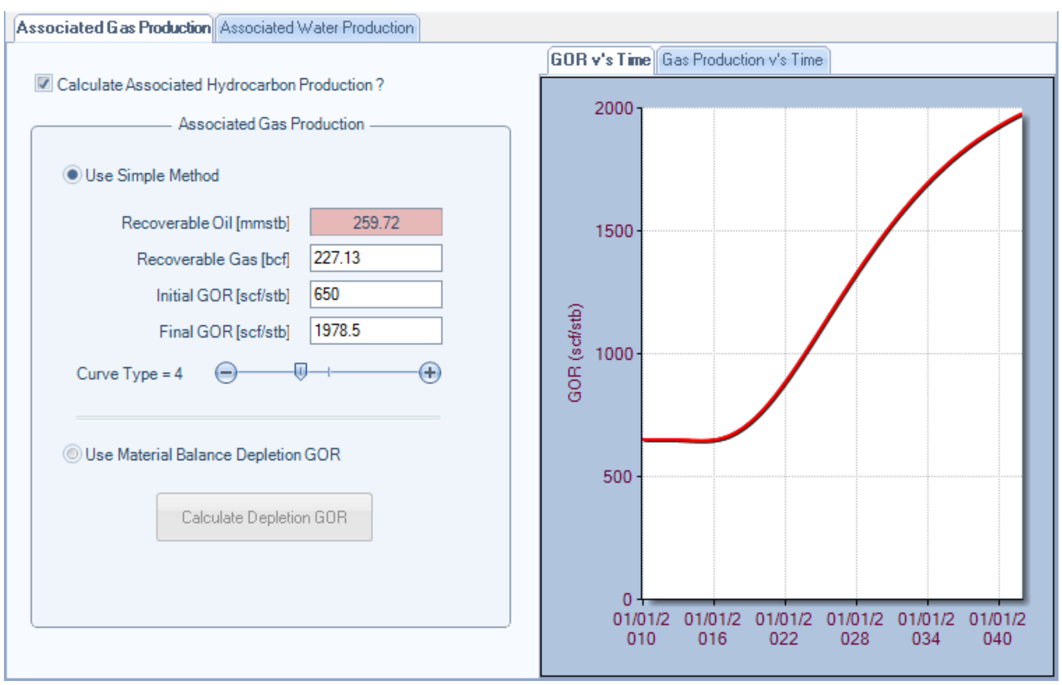
4.1 Secondary Hydrocarbons

To select *Associated Production* simply press the Associated Production tab located on the main application display, as shown below.



The user can choose to calculate an associated gas profile [assuming the main hydrocarbon type is Oil] via either the *Simple Method* or via a *Material Balance Depletion gas/oil ratio (GOR) Method*. If the main hydrocarbon type is Gas/Gas Condensate then the user can only calculate a depletion condensate profile via the *Simple Method*.

The following figure demonstrates the options and the required input.



Simple Method

Based entirely on a paper presented in the Oil and Gas Journal, 21-Feb-1994, entitled “Program predicts realistic solution-gas-drive GOR” by Neal Teague.

The technique allows the user to select the relationship between the production of the secondary phase in relation to the production of the primary phase by simply iterating with the Curve Numbers, the initial and final gas/oil ratios (GOR) or condensate/gas ratios (CGR) and the secondary reserves.

Curve Numbers can exist between 1 and 10. A Curve Number of 1 assumes a constant GOR or CGR.

The user should iterate with all of these variables until a representative GOR or CGR relationship is obtained for the prospect.

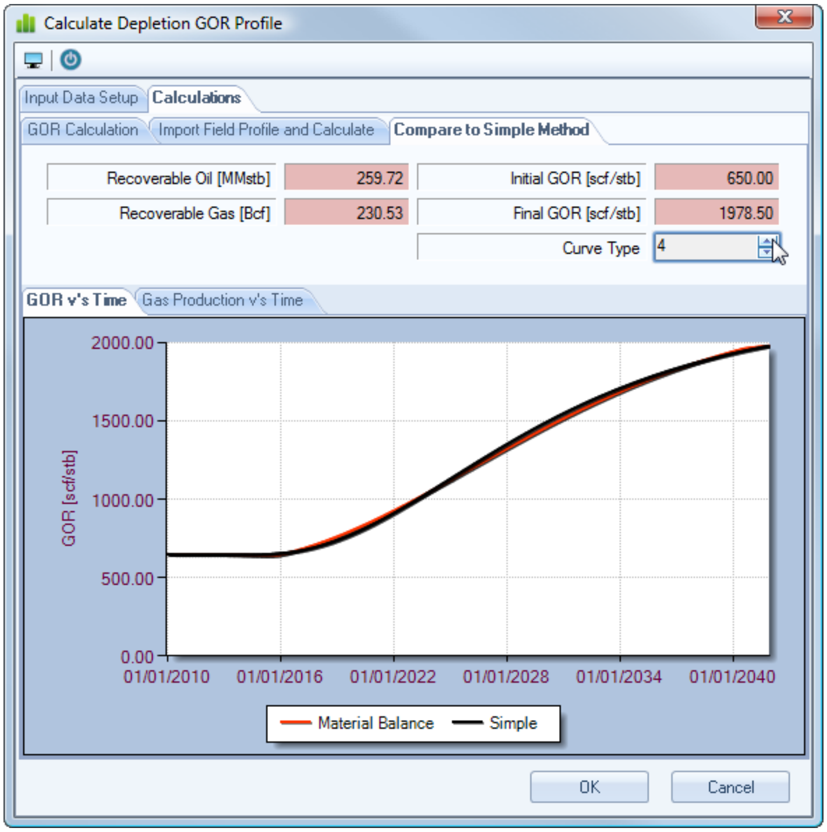
During this iteration process it may become apparent that the technique occasionally calculates negative GOR or CGR versus primary production, wheras in reality this is impossible. In these cases, the user should continue to iterate until a satisfactory relationship is obtained.

Material Balance Depletion GOR Method

The material balance depletion method is provided for oilfields to calculate the primary depletion gas production and is entirely based on the technique outlined by Laurie Dake in "The Practice of Reservoir Engineering", published by Elsevier. [Chapter 3.7 - Volumetric Depletion Fields].

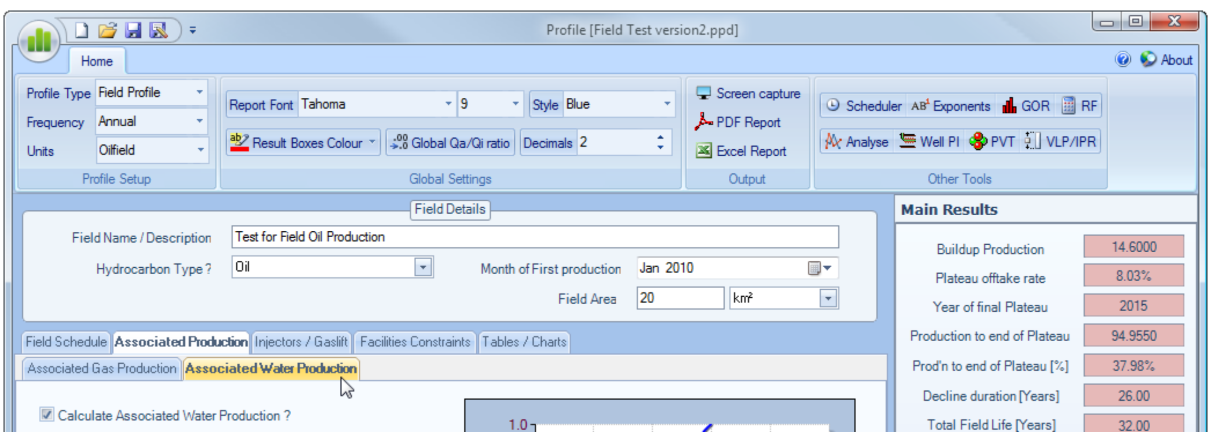
The calculation process is discussed in more detail in the following help topic <u>Calculate Depletion GOR Profile</u>.

It is possible via the Material Balance Depletion GOR Method to calculate the required numbers and curve shape for the Simple Method, an example is included below and is discussed in more detail in the above help topic.

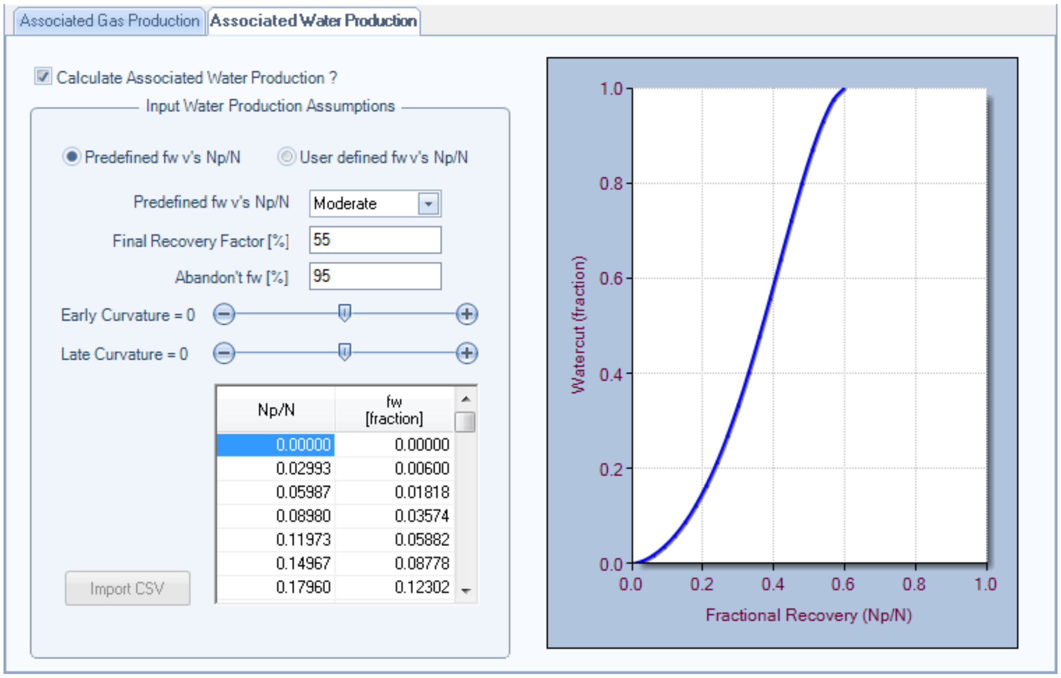


4.2 Water Production

The user can choose to calculate an associated water production profile for both Oil fields and Gas / Gas Condensate fields.



To calculate a water production profile select the tab *Associated Water Production* located in the *Associated Production* panels (as shown above). The following will be displayed.



The user has two options for calculating a water production profile for either a Oil field or a Gas / Gas Condensate.

For Oil Fields the following can be input :

1. *Use Predefined Watercut (fw) v's Recovery Factor (Np/N)*, where Np is the cumulative oil produced and N is the stock tank oil originally in place or STOOIP, and
2. *Use User defined fw v's Np/N*.

For Gas or Gas Condensate Fields the following can be input :

1. *Use Predefined Water Gas Ratio (WGR) v's Recovery Factor (Np/N)*, where Np is the cumulative gas produced and N is the Gas initially in place or GIIP, and
2. *Use User defined WGR v's Np/N*.

Depending on the Field Type, and assuming the first option is selected, the user can select between Favourable, Moderate or Aggressive watercut development trends, from the Predefined fw (or WGR for gas fields) Vs Np/N dropdown box.

The ultimate field recovery factor and field abandonment watercut (or WGR for gas fields) level are also required. The solution then simply looks up, for each calculation period, the production rate and current recovery factor and applies the appropriate watercut/WGR for that period to calculate a water production rate.

The user also has the ability to modify both the early and late curvature of the selected predefined watercut/WGR development trend by toggling the up/down arrows in the *Customise Predefined* group box

Assuming the user wishes to use a specific watercut/WGR development trend then the user can select the second option, *Use User defined fw (or WGR) v's Np/N*. The user should toggle on this option and either manually type in values of ascending order, of recovery and watercut/WGR, or choose to import a comma delimited ASCII file, via the Import CSV button.

This file can be generated in Microsoft Excel and saved as a CSV filetype. An example of what the file should look like is provided below.

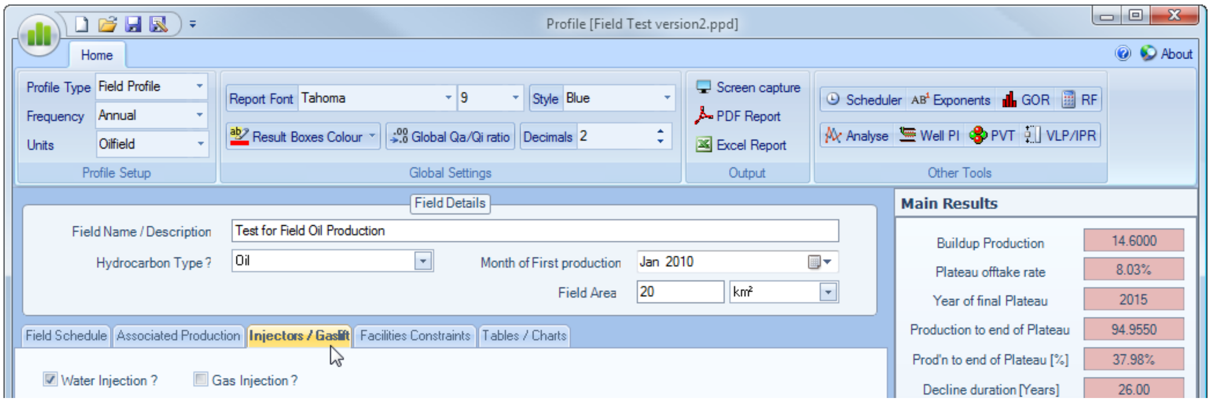
	A	B	C
1	0	0	
2	0.0254	0.006	
3	0.0509	0.0182	
4	0.0763	0.0357	
5	0.1018	0.0588	
6	0.1272	0.0878	
7	0.1527	0.123	
8	0.1781	0.165	
9	0.2035	0.2139	
10	0.229	0.2701	
11	0.2544	0.3333	
12	0.2799	0.4032	
13	0.3053	0.4788	
14	0.3308	0.5586	
15	0.3562	0.6406	
16	0.3816	0.7221	
17	0.4071	0.8	
18	0.4325	0.8709	
19	0.458	0.931	
20	0.4834	0.9764	
21	0.5089	1	
22			
23			

The solution then assumes that the final figures represent the abandonment recovery factor and watercut/WGR (ie., last calculation period), then for each calculation period the current recovery factor is worked out and a watercut/WGR value is interpolated, and therefore for the current oil production rate, an appropriate water production rate is calculated.

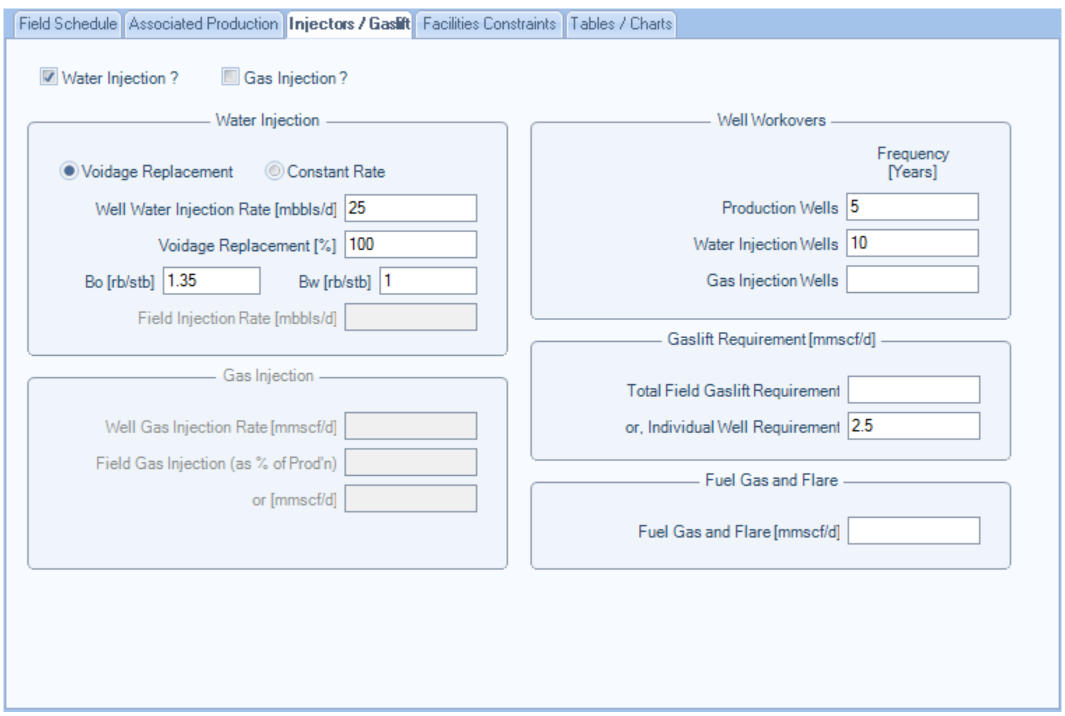
Part V

5 Injectors / Gaslift

To select *Injectors / Gaslift* simply press the Injectors / Gaslift tab located on the main application display, as shown below.



Then the following panel will be displayed.



Assuming the user wishes to model water injection then they should toggle on the *Water Injection ?* check box and the Water Injection group box should become active.

The user can choose to either model a constant field injection rate or model a voidage replacement ratio. Assuming Voidage Replacement is selected then the user should enter the desired voidage replacement percentage and the oil and water formation volume factors.

The Well Water Injection Rate [REQUIRED] is an individual well's water injection rate. The application will calculate when to drill additional water injectors based on the field water injection profile.

Gas injection works in a similar fashion to water injection. Should the user wish to model gas injection then they should toggle on the *Gas Injection ?* check box and the Gas Injection group box should become active.

The user can choose to either model a constant gas injection rate or model gas injection rate as a percentage of total production.

The Well Gas Injection Rate [REQUIRED] is an individual well's gas injection rate. The application will calculate when to drill additional gas injectors based on the field gas injection profile.

The ability to schedule Well Workovers is provided by simply entering their relative frequency in years, ie., a value of 5 years results in a well being workover every 5 years. The application keeps a tally of the cumulative wells drilled [production wells / water injection and gas injection wells] and their frequency of workovers and presents a workover schedule in the main field results table. Cumulative number of workovers, and Reserves per total production wells plus production well workovers are also presented in the Main Results Panel.

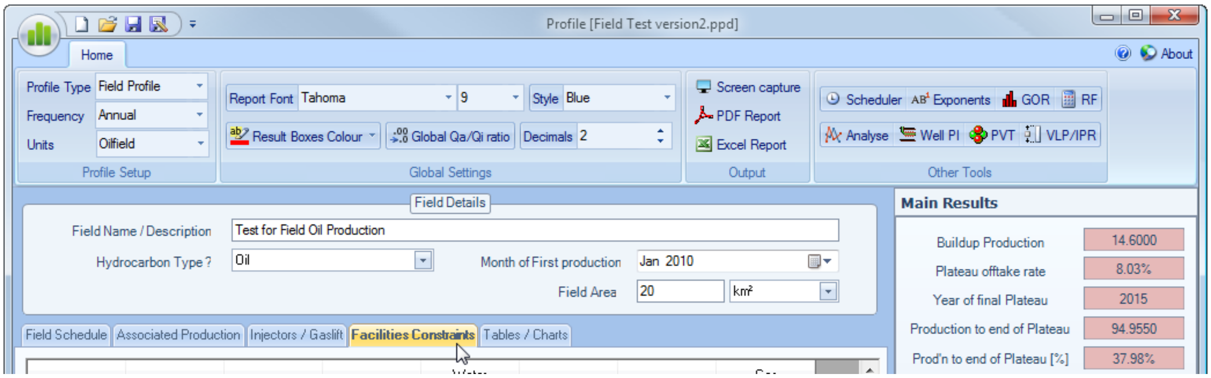
Both gaslift requirement and fuel gas and flare effect the required gas compression levels and ultimate gas sales profile.

The user can choose to either model the gaslift requirement as a constant field requirement or on an individual production well requirement.

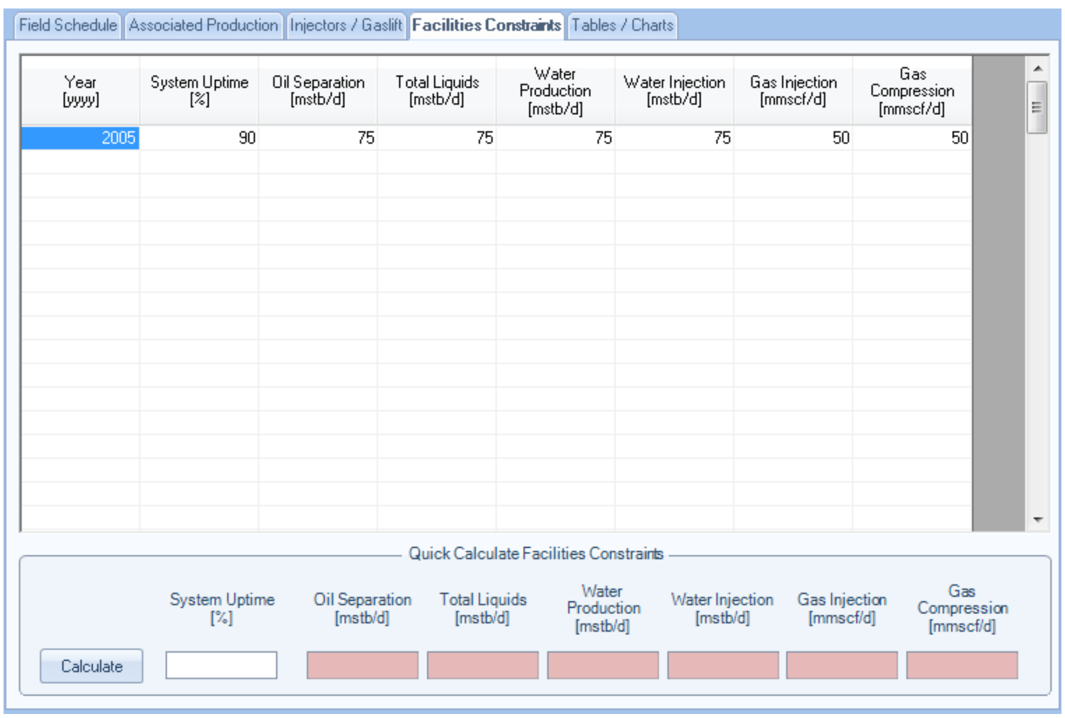
Part VI

6 Facilities Contraints

To select *Facilities Constraints* simply press the Facilities Constraints tab located on the main application display, as shown below.



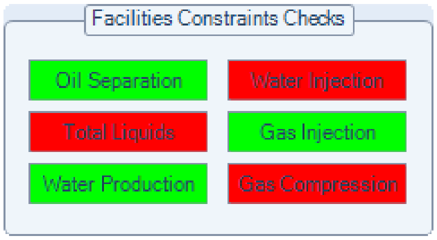
Then the following panel will be displayed.



With a quick look facilities sizing tool located towards the bottom of the panel, as follows.

The intent with these calculation routines are to provide a simple tool to roughly size the facilities constraints.

Should the user enter numbers in the first set of input boxes above, then the application will check whether all the of capacity constraints are met by the various production and injection profiles, and a traffic light system displayed in the Main Results panel located towards the bottom right of the main application panel, as shown below.



Green indicates that the specific facility constraint, for a given system uptime, is not exceeded by the production & injection profiles. Red indicates that the specific facility constraint has been exceeded.

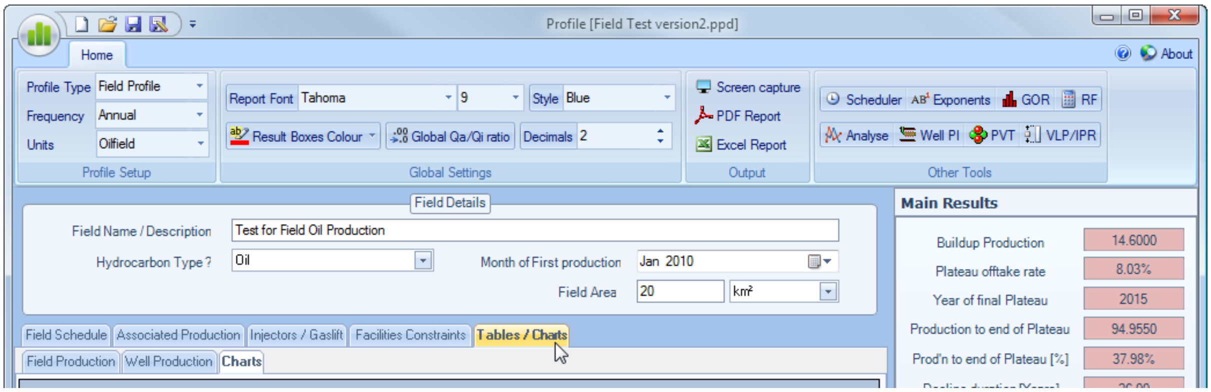
Profile

Production Profile Generation and Analysis

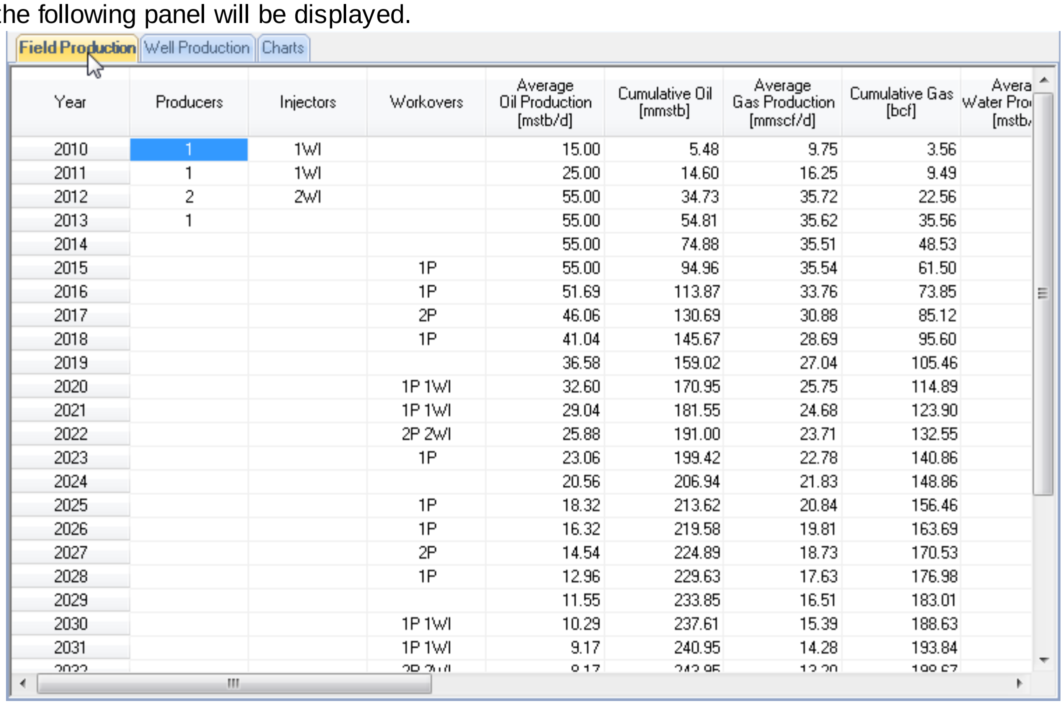
Part VII

7 Table / Charts

To select *Tables / Charts* simply press the Tables / Charts tab located on the main application display, as shown below.

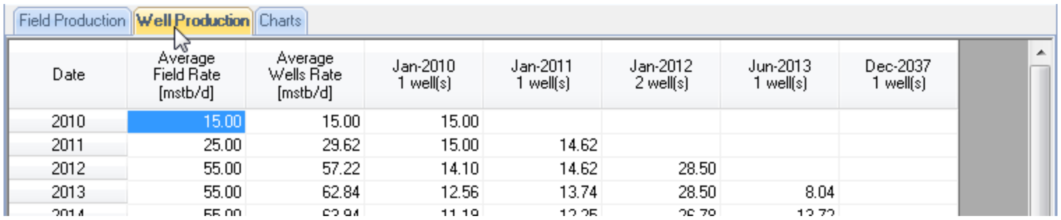


Then the following panel will be displayed.

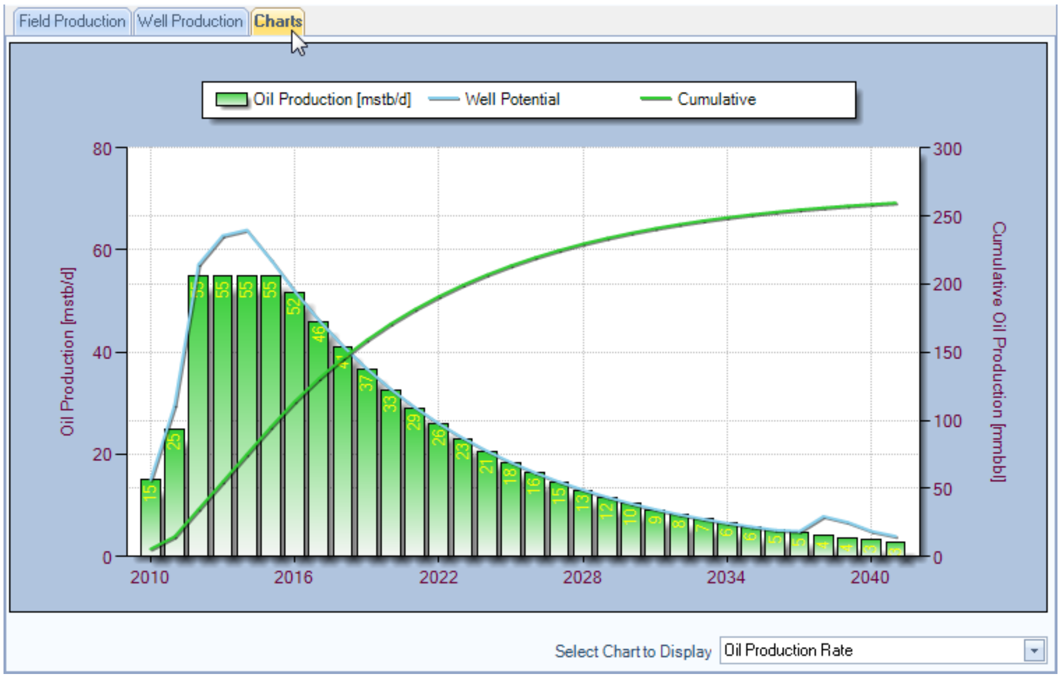


Year	Producers	Injectors	Workovers	Average Oil Production [mstb/d]	Cumulative Oil [mmstb]	Average Gas Production [mmscf/d]	Cumulative Gas [bcf]	Avera Water Pro [mstb/
2010	1	1WI		15.00	5.48	9.75	3.56	
2011	1	1WI		25.00	14.60	16.25	9.49	
2012	2	2WI		55.00	34.73	35.72	22.56	
2013	1			55.00	54.81	35.62	35.56	
2014				55.00	74.88	35.51	48.53	
2015			1P	55.00	94.96	35.54	61.50	
2016			1P	51.69	113.87	33.76	73.85	
2017			2P	46.06	130.69	30.88	85.12	
2018			1P	41.04	145.67	28.69	95.60	
2019				36.58	159.02	27.04	105.46	
2020			1P 1WI	32.60	170.95	25.75	114.89	
2021			1P 1WI	29.04	181.55	24.68	123.90	
2022			2P 2WI	25.88	191.00	23.71	132.55	
2023			1P	23.06	199.42	22.78	140.86	
2024				20.56	206.94	21.83	148.86	
2025			1P	18.32	213.62	20.84	156.46	
2026			1P	16.32	219.58	19.81	163.69	
2027			2P	14.54	224.89	18.73	170.53	
2028			1P	12.96	229.63	17.63	176.98	
2029				11.55	233.85	16.51	183.01	
2030			1P 1WI	10.29	237.61	15.39	188.63	
2031			1P 1WI	9.17	240.95	14.28	193.84	

The field production and injection profiles are shown in the first tab *Field Production*. Individual well production profiles are shown in the following tab *Well Production* (see below), and the charts are shown in the third tab *Charts* (see below).



Date	Average Field Rate [mstb/d]	Average Wells Rate [mstb/d]	Jan-2010 1 well(s)	Jan-2011 1 well(s)	Jan-2012 2 well(s)	Jun-2013 1 well(s)	Dec-2037 1 well(s)
2010	15.00	15.00	15.00				
2011	25.00	29.62	15.00	14.62			
2012	55.00	57.22	14.10	14.62	28.50		
2013	55.00	62.84	12.56	13.74	28.50	8.04	



To select between charts, simply select the required chart via the drop down list box shown above.

Profile

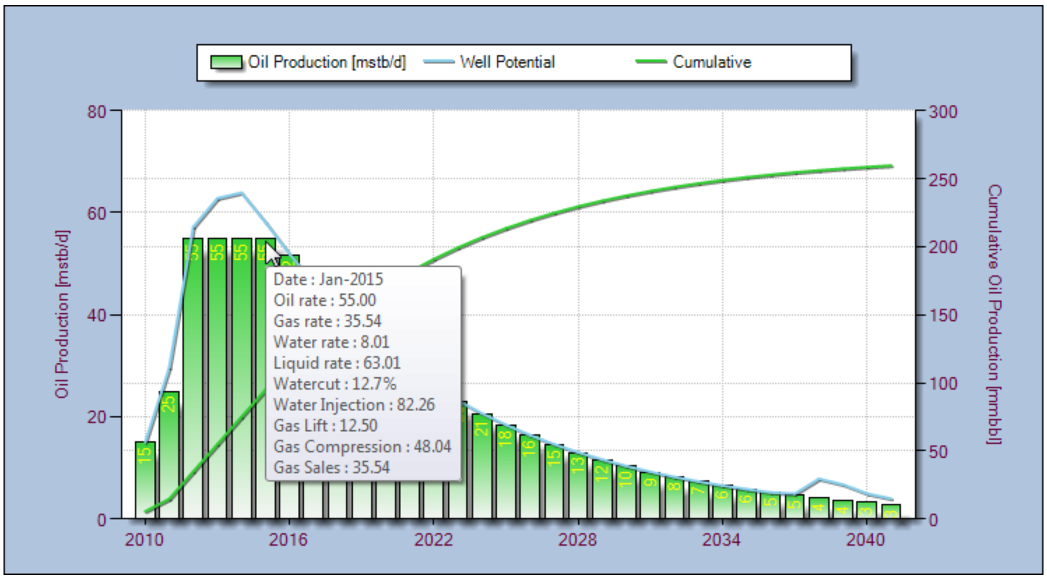
Production Profile Generation and Analysis

Part VIII

8 Chart Operations

Chart tooltips

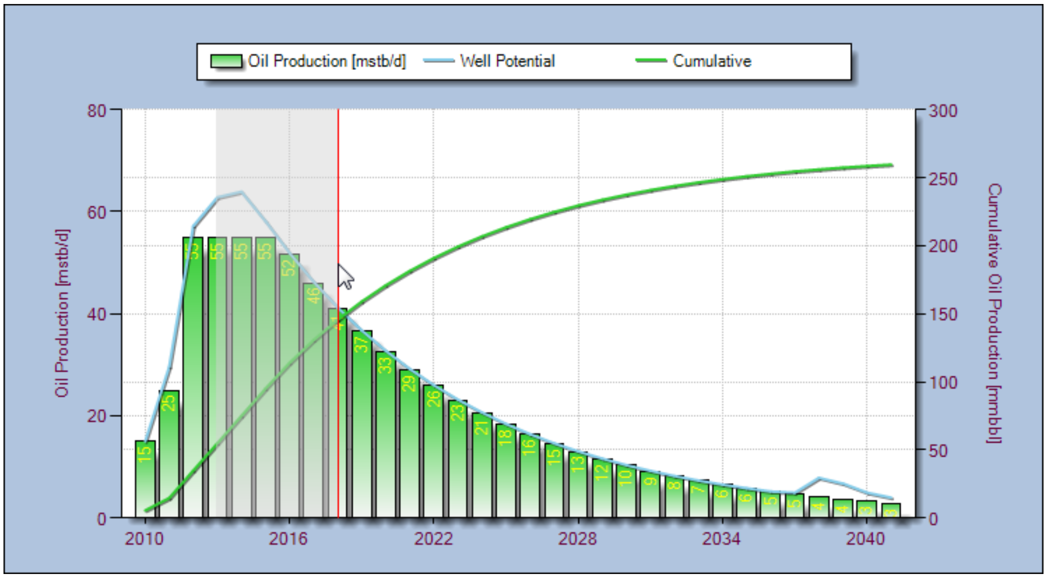
Chart tooltips are provided to allow the user to quickly analyse the displayed production for other calculated profiles. The tooltips will automatically be displayed by simply holding the mouse over the required series point or year.



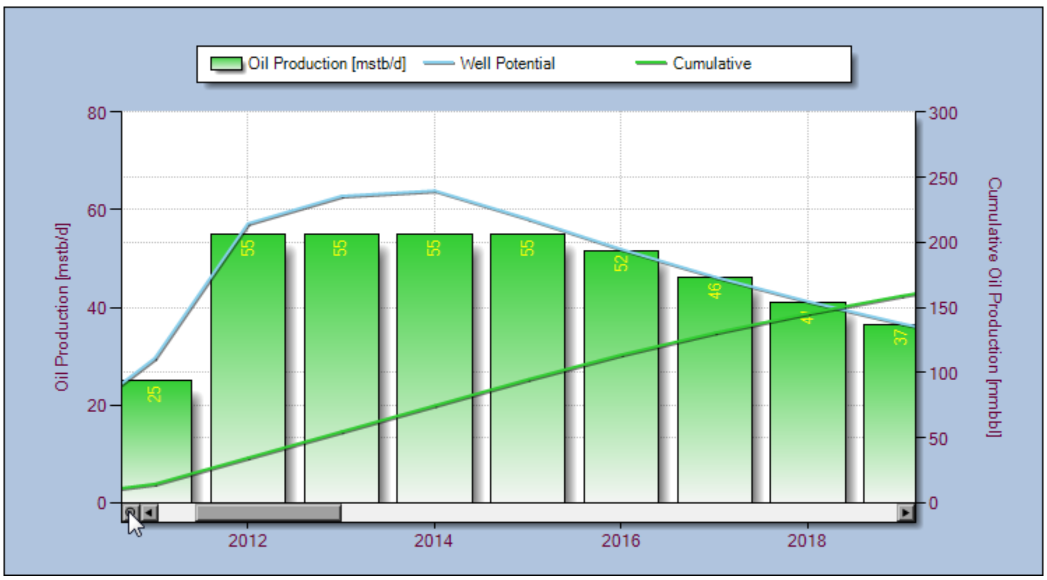
Zooming / Unzooming

The ability to zoom with a chart is provided the allow the user to better analyse the data.

To zoom in simply hold down the left mouse button and drag the mouse over the required zoom area, as shown below.



The resultant zoomed in area should look like the following.

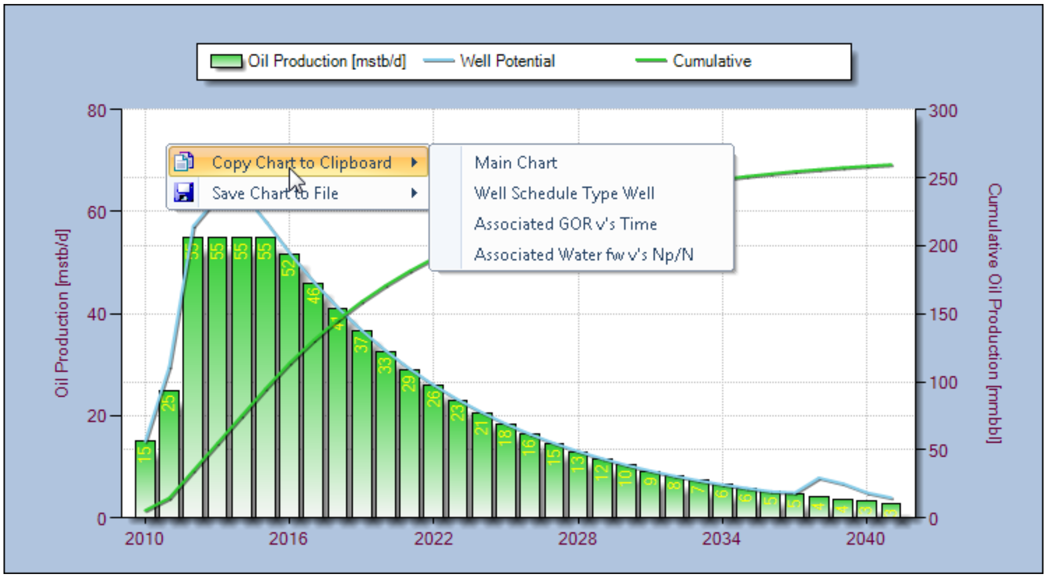


The user can select the scroll bar located at the bottom of the chart to quickly scroll along the production profile.

To unzoom simply select the small Reset Button located on the left of the scroll bar, as shown above.

Chart Context Menu

The context menu associated with the main chart display can be accessed by a single right mouse button click over the main chart, as shown below.



The user can choose to save a copy of any of the charts to the clipboard, or as a graphic file (either PNG, BMP or JPG format).

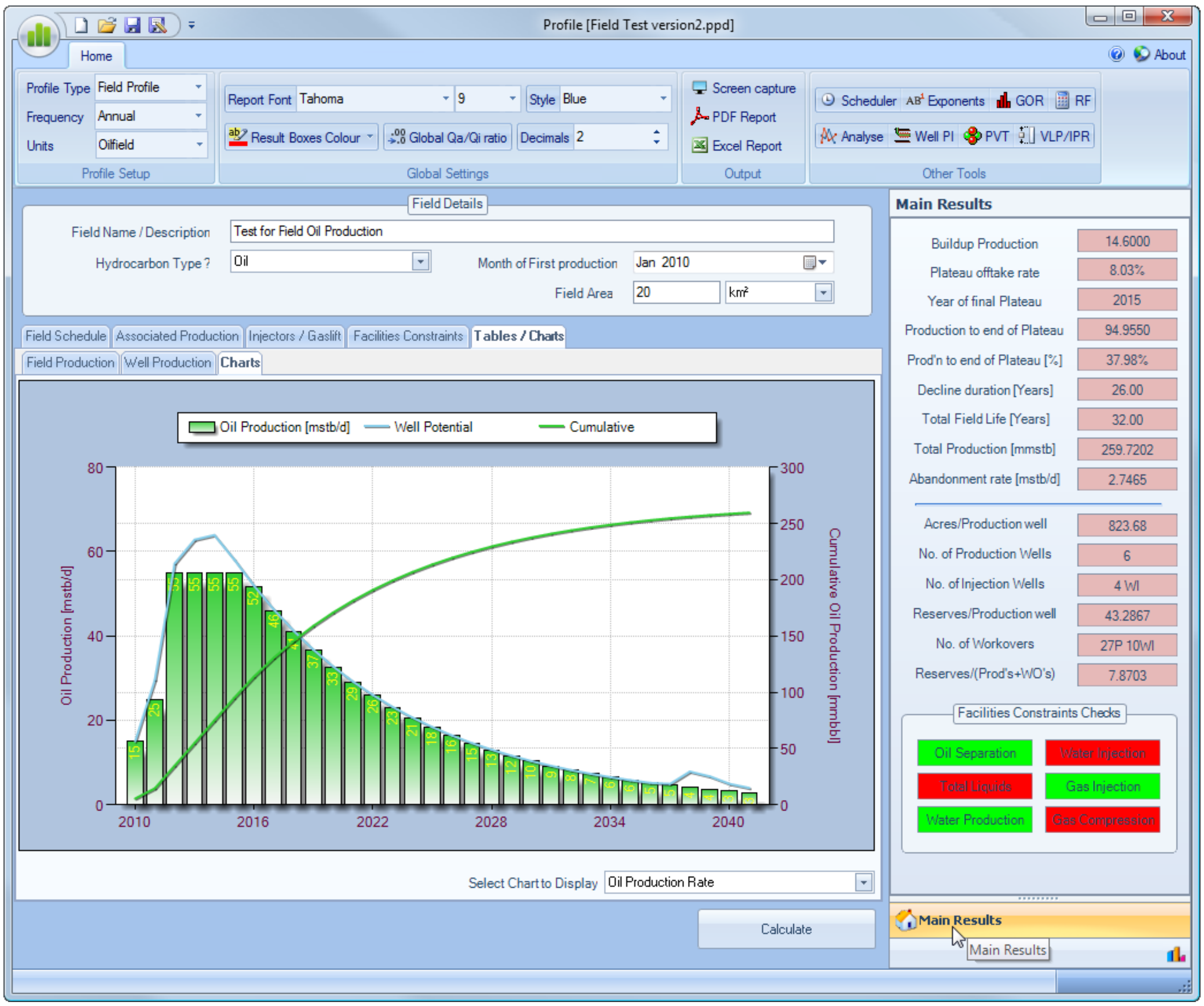
Profile

Production Profile Generation and Analysis

Part IX

9 Main Results Panel

Once all the appropriate data has been entered to perform a calculation, and the user has pressed the large Calculate button located towards the bottom right of the application, the Main Results panel will be populated with results. See below.



If either the ***Chart Properties*** or ***Tools*** menu items are displayed in the navigation bar on the right, to return to the ***Main Results*** section simply press the ***Main Results*** navigation bar, as shown above.

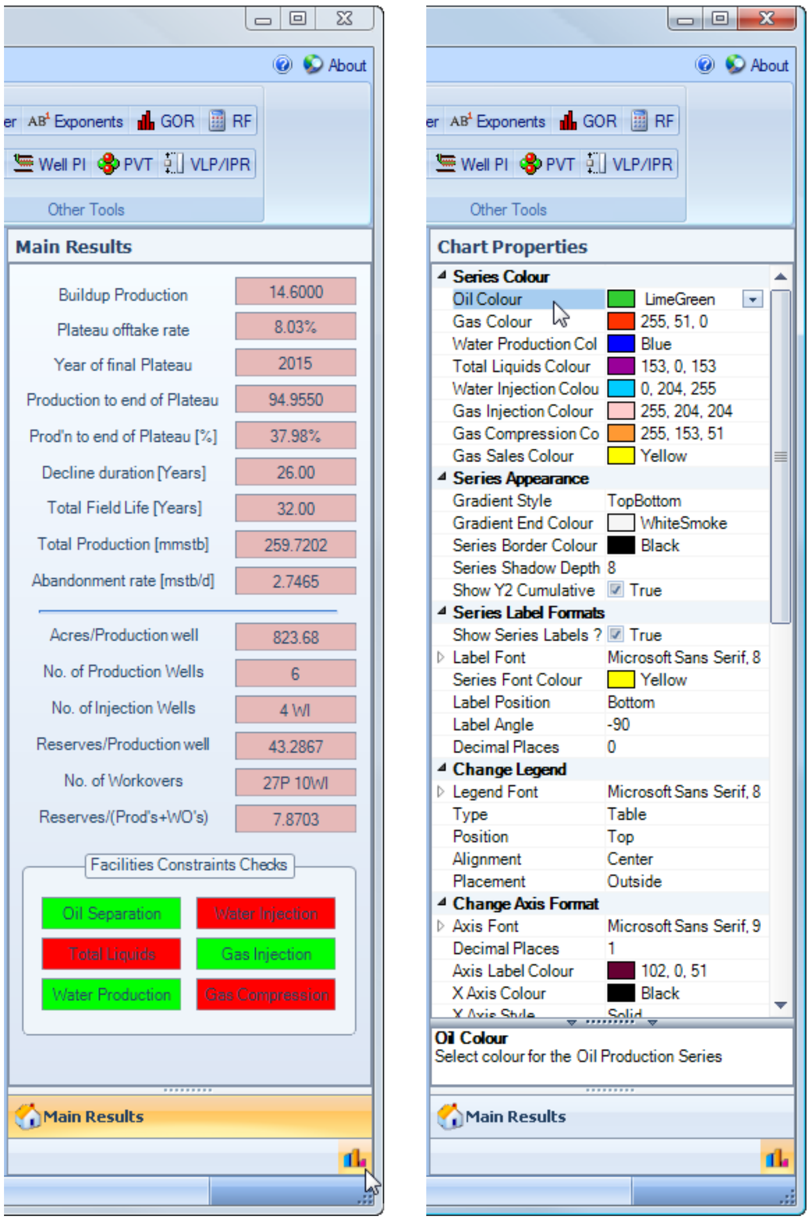
The intent with displaying these results throughout the application is to help guide the user in designing the appropriate production and injection profiles, given the user's knowledge of analogue fields for well spacing, recovery/well, plateau offtake rates, decline rates, etc.

Part X

10 Change Chart Settings

The user can change individual series appearance by selecting the chart icon located at the bottom right-hand corner of the application, as shown below.

This will display the Chart Properties grid which allows the user to change any aspect of the chart appearance.

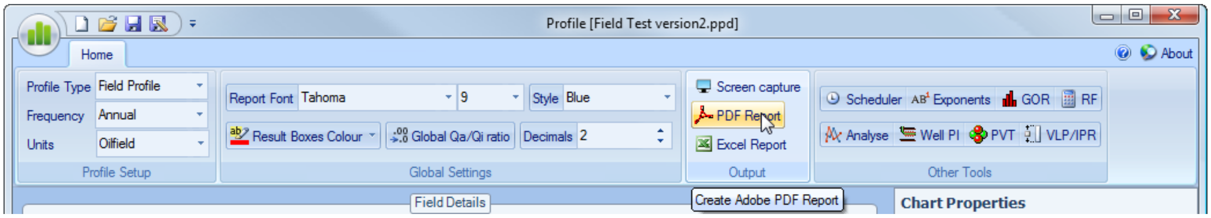


Part XI

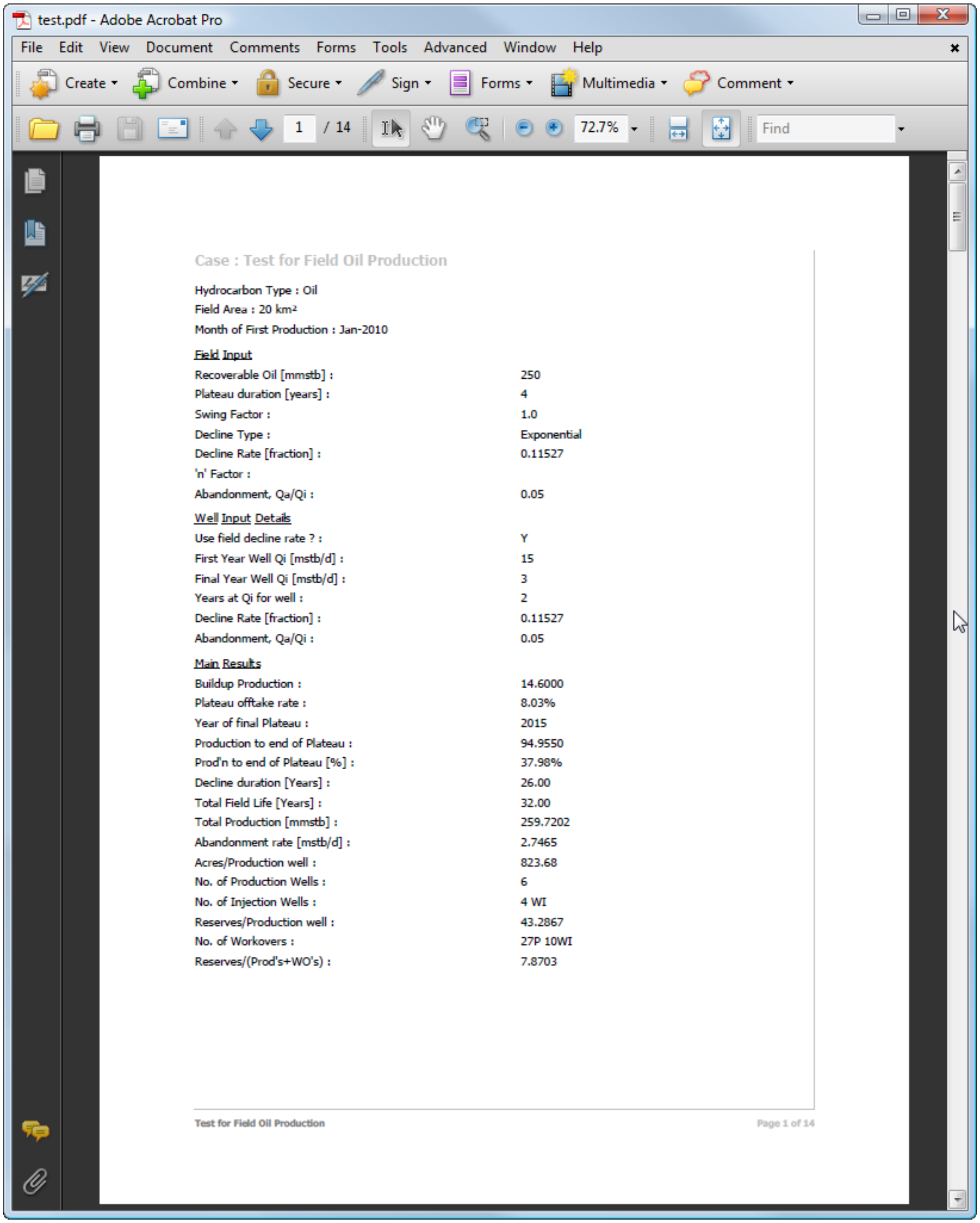
11 Create Reports

Profile Reports can either be created in Adobe Acrobat format ("PDF") or Microsoft Excel format ("XLS").

To access the Create Report option, select the Create Report menu item located under the Main File menu item, as shown below.



Assuming the Create Abode PDF Report is selected the user will be prompted for a report PDF filename, and a file similar to the following should be created.



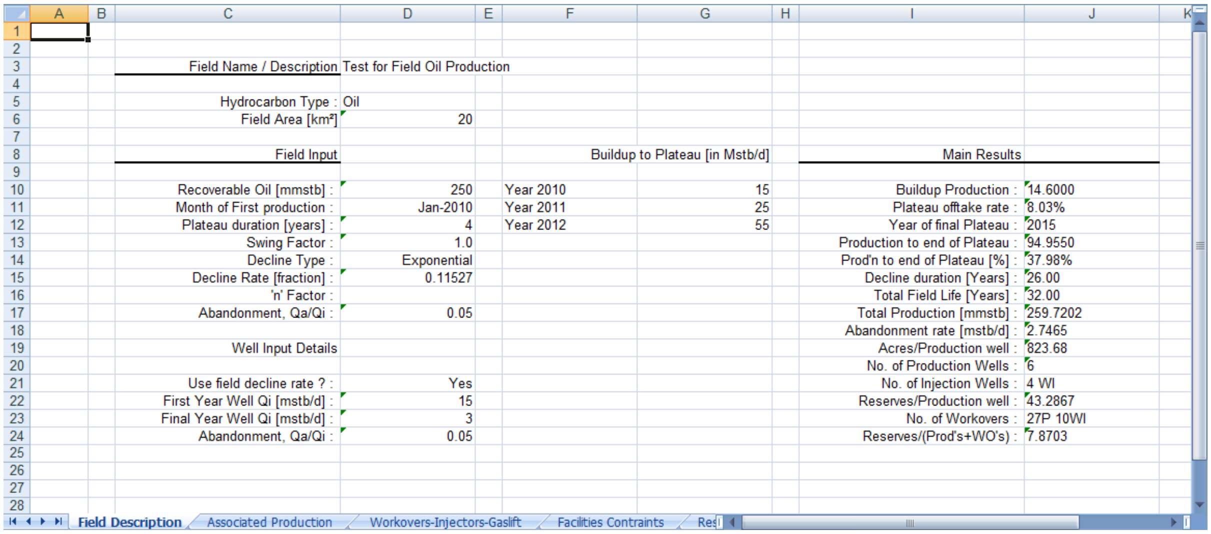
Case : Test for Field Oil Production

Hydrocarbon Type : Oil
Field Area : 20 km²
Month of First Production : Jan-2010

Field Input	
Recoverable Oil [mmstb] :	250
Plateau duration [years] :	4
Swing Factor :	1.0
Decline Type :	Exponential
Decline Rate [fraction] :	0.11527
'n' Factor :	
Abandonment, Qa/Qi :	0.05
Well Input Details	
Use field decline rate ? :	Y
First Year Well Qi [mstb/d] :	15
Final Year Well Qi [mstb/d] :	3
Years at Qi for well :	2
Decline Rate [fraction] :	0.11527
Abandonment, Qa/Qi :	0.05
Main Results	
Buildup Production :	14.6000
Plateau offtake rate :	8.03%
Year of final Plateau :	2015
Production to end of Plateau :	94.9550
Prod'n to end of Plateau [%] :	37.98%
Decline duration [Years] :	26.00
Total Field Life [Years] :	32.00
Total Production [mmstb] :	259.7202
Abandonment rate [mstb/d] :	2.7465
Acres/Production well :	823.68
No. of Production Wells :	6
No. of Injection Wells :	4 WI
Reserves/Production well :	43.2867
No. of Workovers :	27P 10WI
Reserves/(Prod's+WO's) :	7.8703

Test for Field Oil Production Page 1 of 14

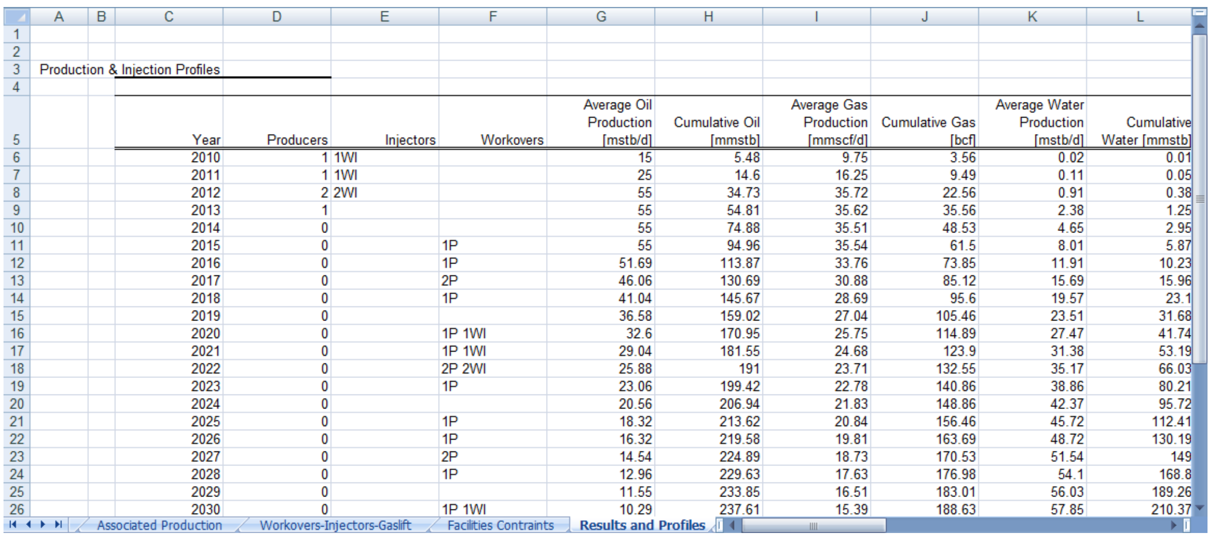
Assuming the Create Microsoft Excel Report is selected the user will be prompted for a report XLS filename, and a file similar to the following should be created.



Field Name / Description Test for Field Oil Production

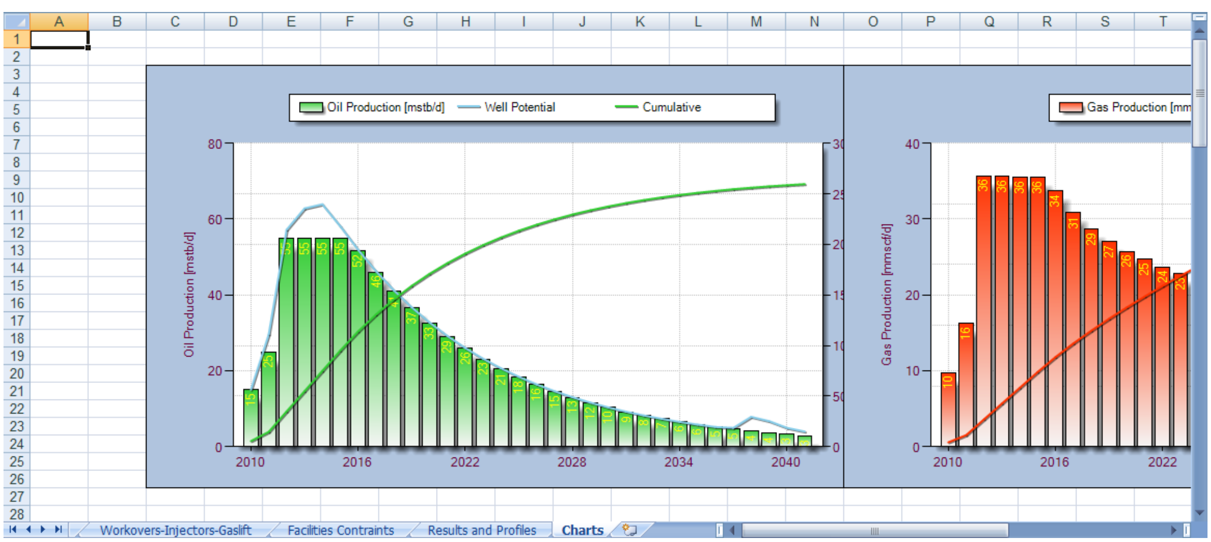
Hydrocarbon Type : Oil
Field Area [km²] 20

Field Input		Buildup to Plateau [in Mstb/d]		Main Results	
Recoverable Oil [mmstb] :	250	Year 2010	15	Buildup Production :	14.6000
Month of First production :	Jan-2010	Year 2011	25	Plateau offtake rate :	8.03%
Plateau duration [years] :	4	Year 2012	55	Year of final Plateau :	2015
Swing Factor :	1.0			Production to end of Plateau :	94.9550
Decline Type :	Exponential			Prod'n to end of Plateau [%] :	37.98%
Decline Rate [fraction] :	0.11527			Decline duration [Years] :	26.00
'n' Factor :				Total Field Life [Years] :	32.00
Abandonment, Qa/Qi :	0.05			Total Production [mmstb] :	259.7202
				Abandonment rate [mstb/d] :	2.7465
Well Input Details				Acres/Production well :	823.68
				No. of Production Wells :	6
Use field decline rate ? :	Yes			No. of Injection Wells :	4 WI
First Year Well Qi [mstb/d] :	15			Reserves/Production well :	43.2867
Final Year Well Qi [mstb/d] :	3			No. of Workovers :	27P 10WI
Abandonment, Qa/Qi :	0.05			Reserves/(Prod's+WO's) :	7.8703



Production & Injection Profiles

Year	Producers	Injectors	Workovers	Average Oil Production [mstb/d]	Cumulative Oil [mmstb]	Average Gas Production [mmscf/d]	Cumulative Gas [bcf]	Average Water Production [mstb/d]	Cumulative Water [mmstb]
2010	1	1WI		15	5.48	9.75	3.56	0.02	0.01
2011	1	1WI		25	14.6	16.25	9.49	0.11	0.05
2012	2	2WI		55	34.73	35.72	22.56	0.91	0.38
2013	1			55	54.81	35.62	35.56	2.38	1.25
2014	0			55	74.88	35.51	48.53	4.65	2.95
2015	0		1P	55	94.96	35.54	61.5	8.01	5.87
2016	0		1P	51.69	113.87	33.76	73.85	11.91	10.23
2017	0		2P	46.06	130.69	30.88	85.12	15.69	15.96
2018	0		1P	41.04	145.67	28.69	95.6	19.57	23.1
2019	0			36.58	159.02	27.04	105.46	23.51	31.68
2020	0		1P 1WI	32.6	170.95	25.75	114.89	27.47	41.74
2021	0		1P 1WI	29.04	181.55	24.68	123.9	31.38	53.19
2022	0		2P 2WI	25.88	191	23.71	132.55	35.17	66.03
2023	0		1P	23.06	199.42	22.78	140.86	38.86	80.21
2024	0			20.56	206.94	21.83	148.86	42.37	95.72
2025	0		1P	18.32	213.62	20.84	156.46	45.72	112.41
2026	0		1P	16.32	219.58	19.81	163.69	48.72	130.19
2027	0		2P	14.54	224.89	18.73	170.53	51.54	149
2028	0		1P	12.96	229.63	17.63	176.98	54.1	168.8
2029	0			11.55	233.85	16.51	183.01	56.03	189.26
2030	0		1P 1WI	10.29	237.61	15.39	188.63	57.85	210.37

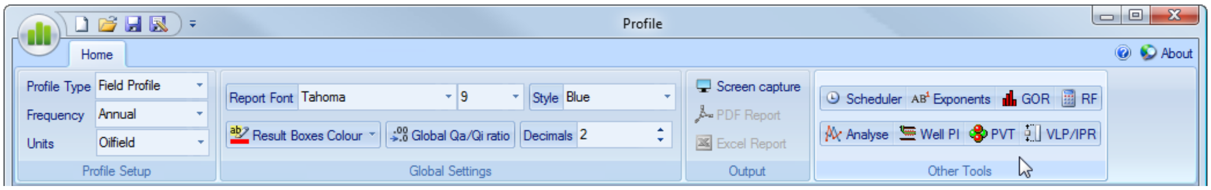


Part XII

12 Tools Menu Items

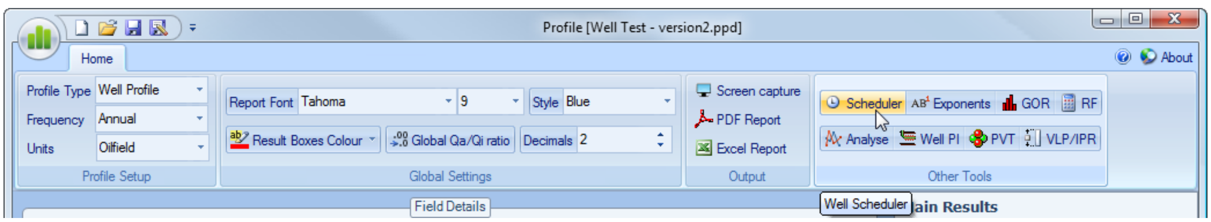
Numerous tools are provided to aid the user with production profile generation.

To access these tools, simply select any of Tools in the ***Other Tools*** menu bar, as shown below.

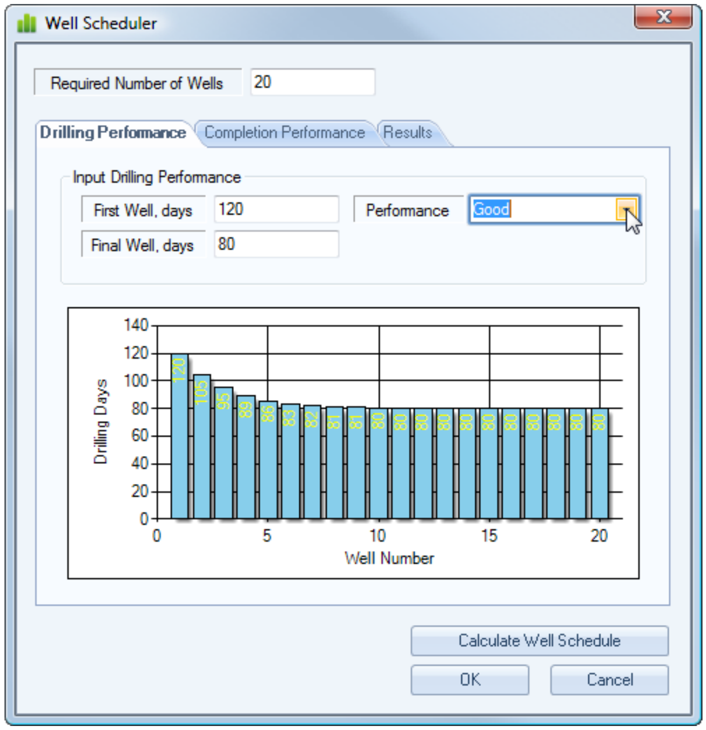


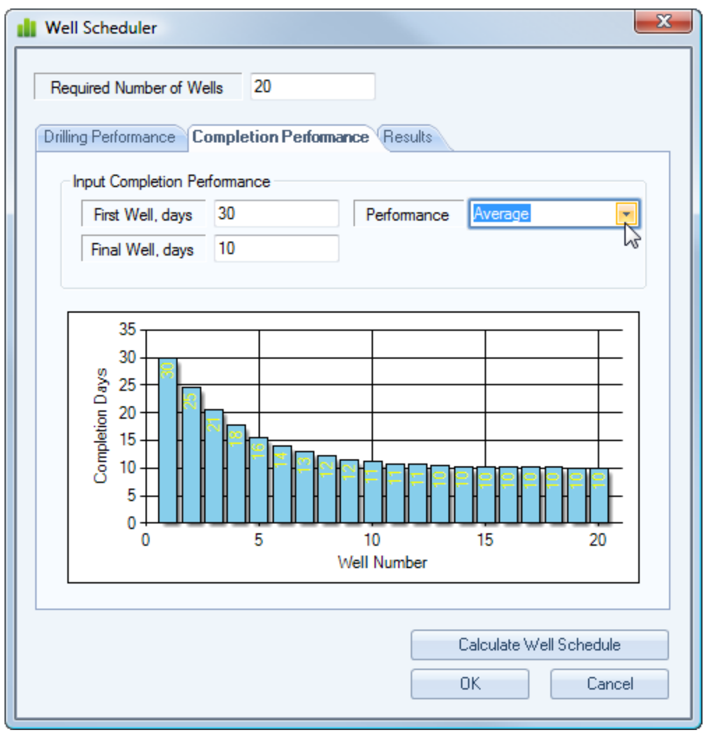
12.1 Well Scheduler

This tool is provided to allow the user to quickly schedule the first production dates for a series of production wells given a knowledge of their drilling and completion durations and improvement performance.

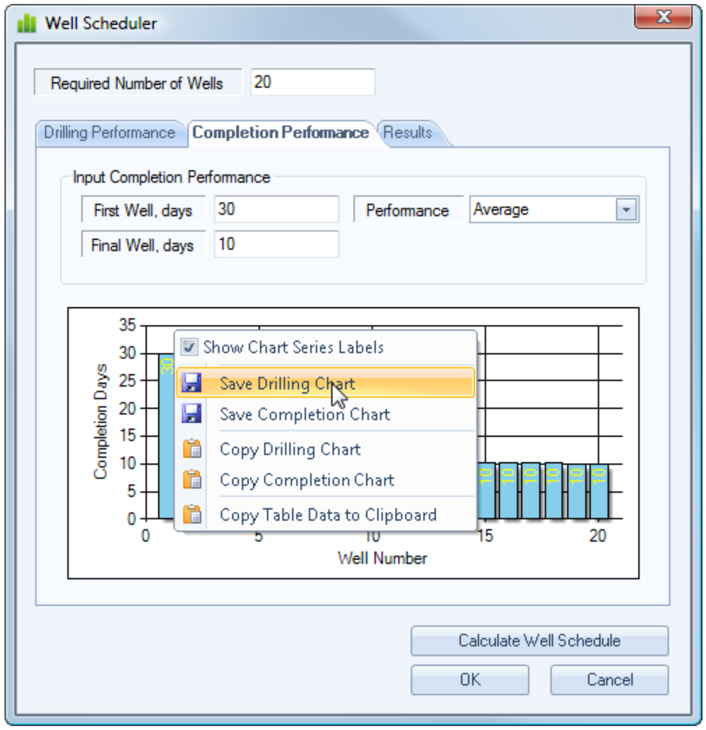


Once the tool is selected, the following input form should be displayed. Once the user enters data for the required number of wells and the drilling and/or completion performance (first well & last well duration and selects a performance), the performance chart will be displayed.

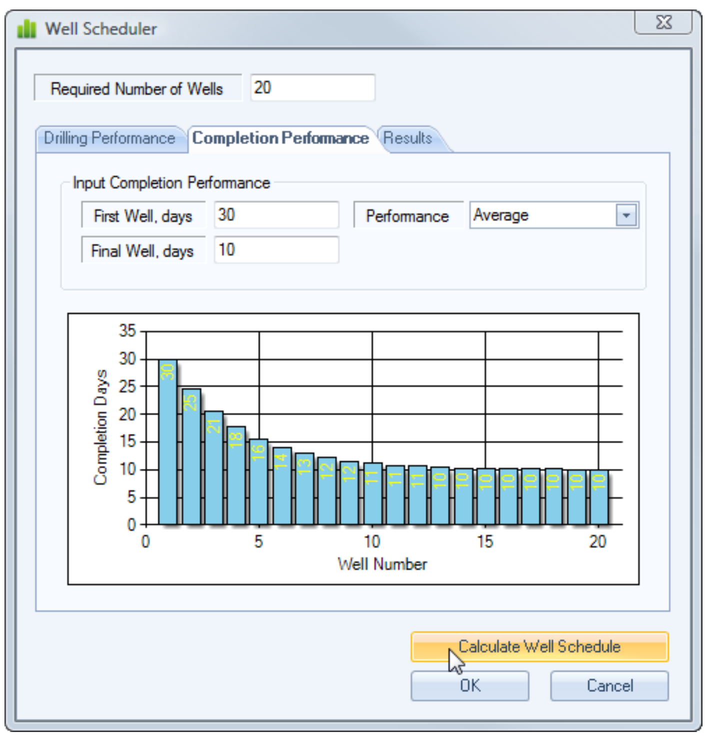




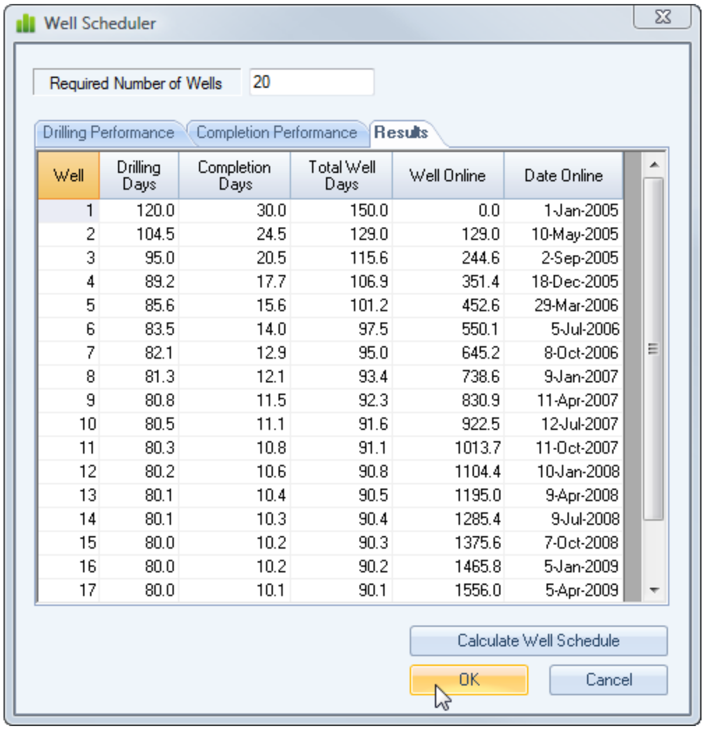
The user can select to save the chart to a file or the clipboard by selecting the context menu [single right mouse click] on either chart or calculation table, as shown below.



Once the user is happy with the drilling and completion performance then they should press the Calculate button in the toolbar, as shown below, to calculate the well schedule.



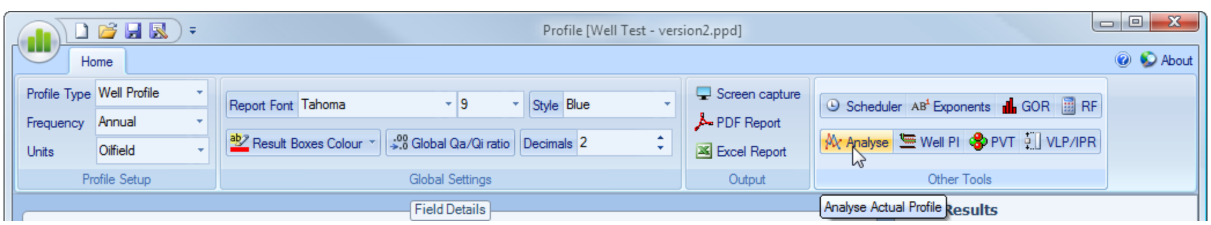
Then the following results should be displayed in the third tab *Results*.



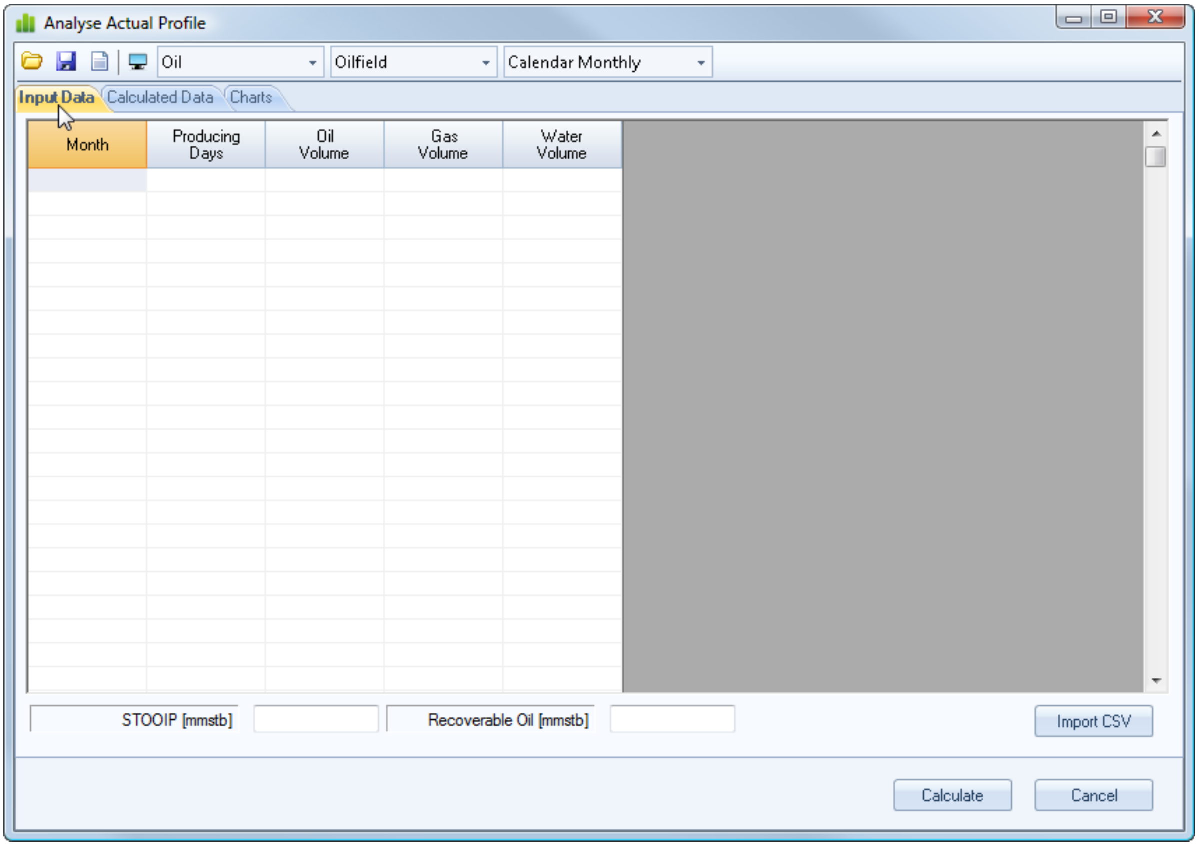
To transfer the results back to the Well Schedule / Input Well Schedule section of the main application select the OK button, otherwise select the Cancel button to return to the main application without the results of the Well Scheduler calculation.

12.2 Analyse Actual Profile

The following tool is provided to allow the user to quickly analyse the buildup, plateau and decline characteristics of a known well or field.



Once the tool is selected, the following input form should be displayed.



The User can import a comma delimited ASCII production history file, via the *Import CSV* button. An example is shown below of the required input format, in both a text editor or Microsoft Excel format.

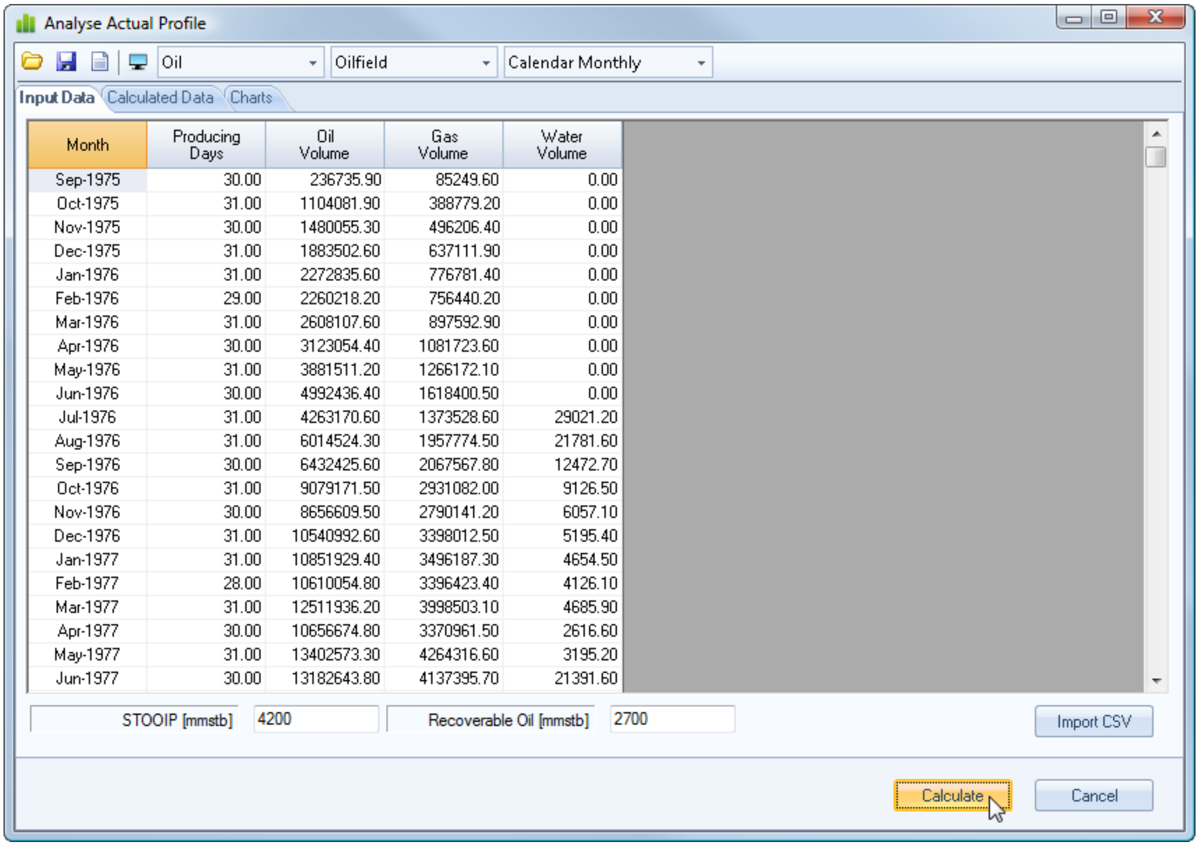
The intent with the production history file is to have the input data frequency as MONTHLY. The user can choose to calculate and display the history data as either Monthly, semi-annually or annually later after successfully pressing the *Calculate* button.

```
Month,Producing Days,Oil volume (bbl),Gas Volume (MMCF),Water volume (bbl)
Sep-1975,30,236735.8688,85.24961338,0
Oct-1975,31,1104081.798,388.779202,0
Nov-1975,30,1480055.191,496.2064282,0
Dec-1975,31,1883502.474,637.1119615,0
Jan-1976,31,2272835.423,776.7814813,0
Feb-1976,29,2260218.064,756.4402314,0
Mar-1976,31,2608107.455,897.5929674,0
Apr-1976,30,3123054.2,1081.723657,0
May-1976,31,3881510.939,1266.172178,0
Jun-1976,30,4992436.051,1618.400697,0
Jul-1976,31,4263170.32,1373.528775,29021.18334
Aug-1976,31,6014523.886,1957.774675,21781.61203
Sep-1976,30,6432425.152,2067.567984,12472.69323
Oct-1976,31,9079170.91,2931.082295,9126.51431
Nov-1976,30,8656608.895,2790.141447,6057.08703
Dec-1976,31,10540991.94,3398.012862,5195.38306
Jan-1977,31,10851928.7,3496.187645,4654.4594
Feb-1977,28,10610054.06,3396.423702,4126.11536
Mar-1977,31,12511935.35,3998.503511,4685.90845
Apr-1977,30,10656674.13,3370.961825,2616.56096
May-1977,31,13402572.45,4264.317032,3195.22348
Jun-1977,30,13182642.95,4137.396108,21391.64381
Jul-1977,31,12019348.88,3771.18298,40386.87001
```

	Month	Producing Days	Oil Volume [bbls]	Gas Volume [Mcf]	Water Volume [bbls]
2	Sep-75	30	236735.90	85249.60	0.00
3	Oct-75	31	1104081.90	388779.20	0.00
4	Nov-75	30	1480055.30	496206.40	0.00
5	Dec-75	31	1883502.60	637111.90	0.00
6	Jan-76	31	2272835.60	776781.40	0.00
7	Feb-76	29	2260218.20	756440.20	0.00
8	Mar-76	31	2608107.60	897592.90	0.00
9	Apr-76	30	3123054.40	1081723.60	0.00
10	May-76	31	3881511.20	1266172.10	0.00
11	Jun-76	30	4992436.40	1618400.50	0.00
12	Jul-76	31	4263170.60	1373528.60	29021.20
13	Aug-76	31	6014524.30	1957774.50	21781.60
14	Sep-76	30	6432425.60	2067567.80	12472.70
15	Oct-76	31	9079171.50	2931082.00	9126.50
16	Nov-76	30	8656609.50	2790141.20	6057.10
17	Dec-76	31	10540992.60	3398012.50	5195.40
18	Jan-77	31	10851929.40	3496187.30	4654.50
19	Feb-77	28	10610054.80	3396423.40	4126.10
20	Mar-77	31	12511936.20	3998503.10	4685.90
21	Apr-77	30	10656674.80	3370961.50	2616.60
22	May-77	31	13402573.30	4264316.60	3195.20
23	Jun-77	30	13182643.80	4137395.70	21391.60
24	Jul-77	31	[illegible]	[illegible]	[illegible]

Forties

Once a ASCII CSV file has been successfully imported, the User should input approximate values for Originally-In-Place and Ultimate Recovery volumes. These numbers are used to calculate the production offtake rates and for the Watercut Vs Oil Recovery plot, see picture below.

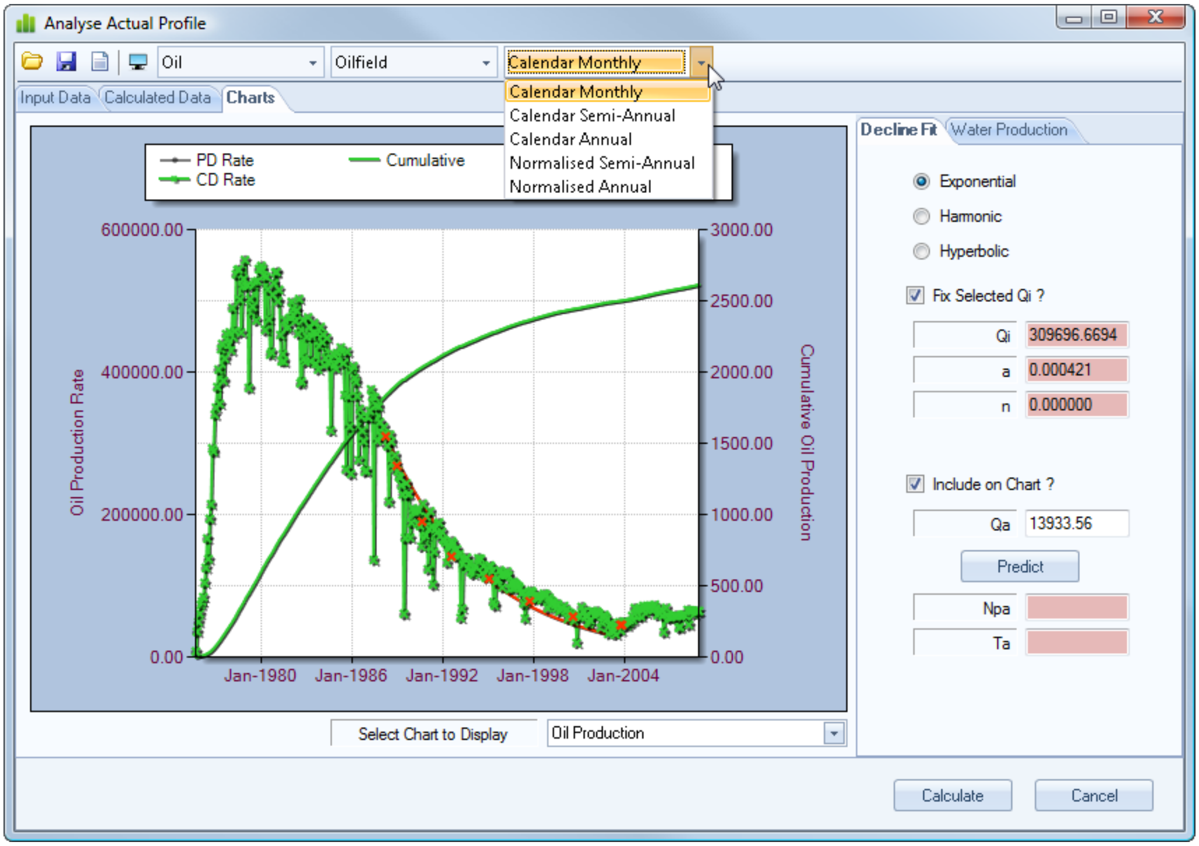


The User should then press the *Calculate* button located at towards the bottom right of the input panel, then *Calculated Data* and *Charts* Panels should become populated with data.

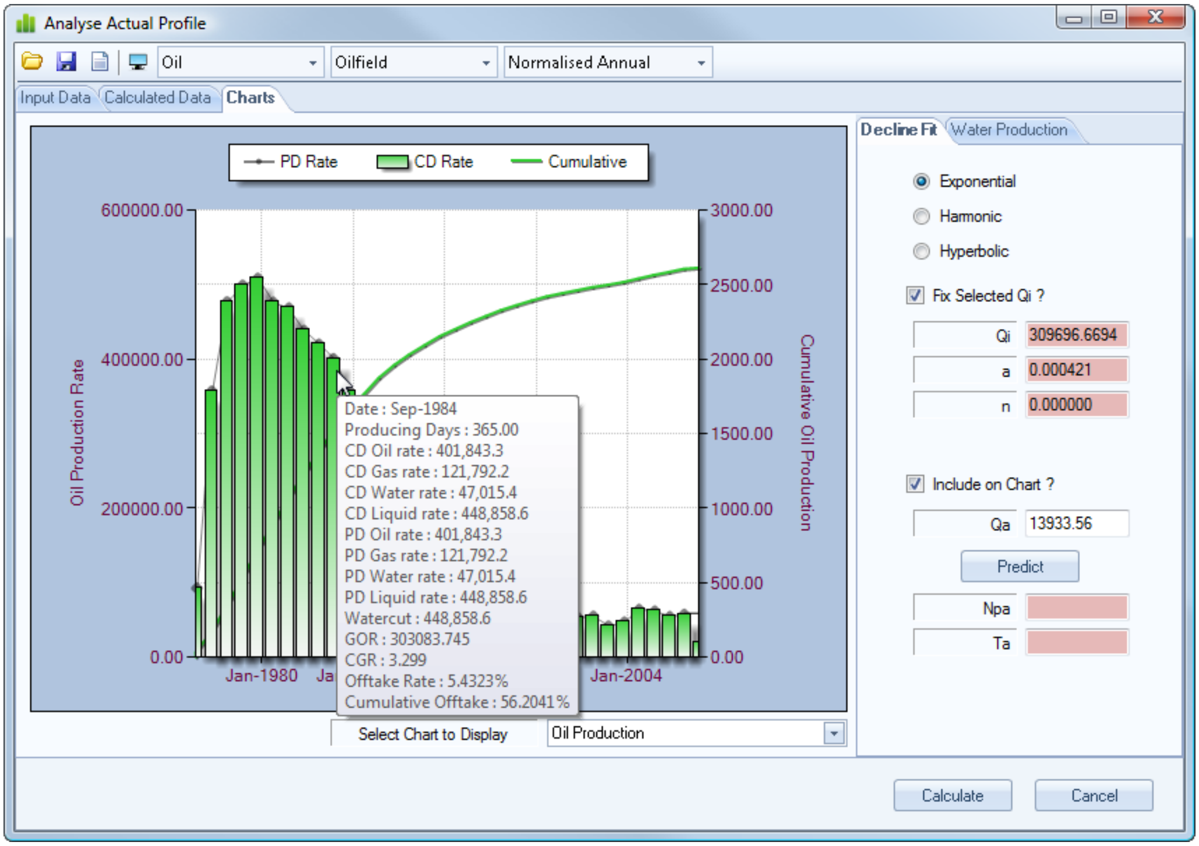
As with all tables within the application, the user has the ability to copy both tables to the clipboard via the standard windows shortcut key, CTRL+C.

Within the Charts panel, the user can select between chart frequency by selecting the *Calculation Frequency* dropdown menu item, as shown below.

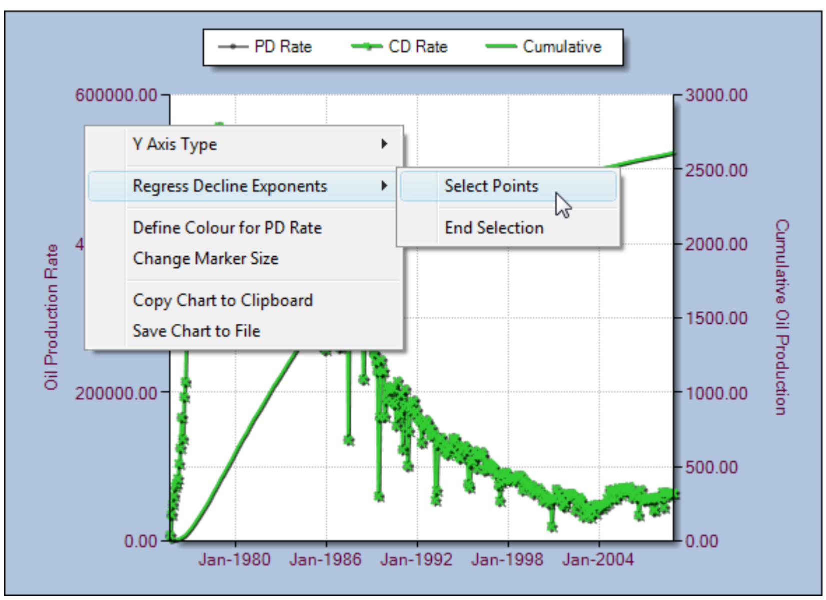
Normalised Semi-Annual and Normalised Annual options are provided to normalise the production profile relative to the start date, ie., A normalised Semi-Annual profile beginning in Sep-1975 will have reporting periods of September and March of each year (6 monthly intervals) and a normalised Annual profile beginning in Sep-1975 will have reporting periods of September of each year (12 monthly intervals). The purpose for adding these two options are to more accurately calculate the offtake rate and cumulative offtake for the plateau and end of plateau periods.



The User has the ability to quickly scan the profile for whatever Frequency period and tooltips are provided to quickly analyse the various production rates, ratios and offtake percentages, see below.

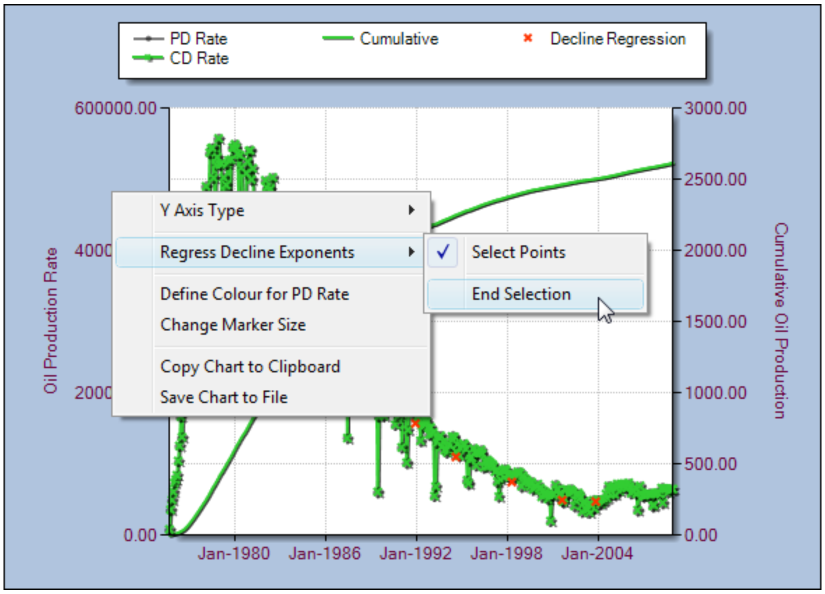


In particular the offtake rate and cumulative offtake figures can be used when designing the required production profile back in the main application.

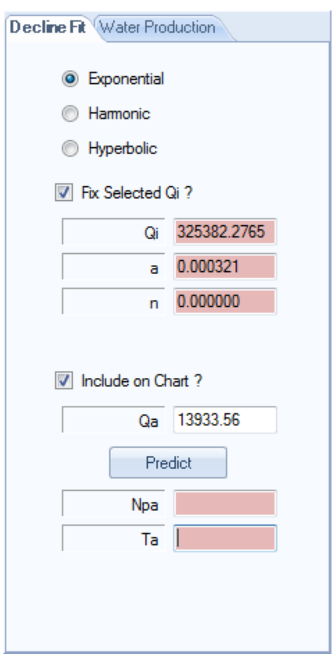


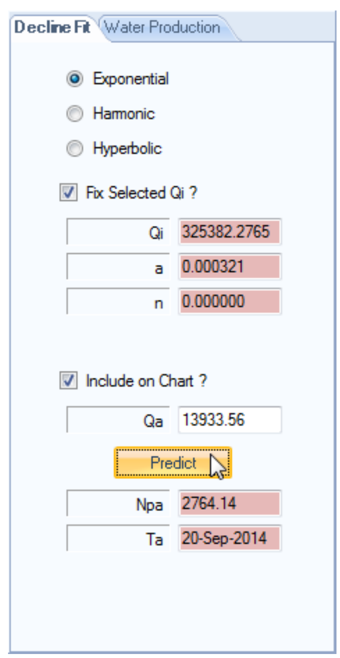
The User can also change the Y Axis Type between Linear and Logarithmic, via the context menu associated with the chart. The context menu is accessed via a single right mouse click while the mouse is located over the chart. See picture above.

Provision is also made to do decline curve analysis. Should the User want to calculate the decline exponents for either Exponential, Harmonic or Hyperbolic declines, select the *Select Points* context menu item, as shown above, to toggle on the points selection. The user should then select points on the chart to conduct the regression analysis. Once the User is happy with the selection of points, access the context menu again by a single right mouse button click while the mouse is located over the axis areas (not in the display chart area - as this may continue to add regression points), then select the *End Selection* menu item. See picture below.



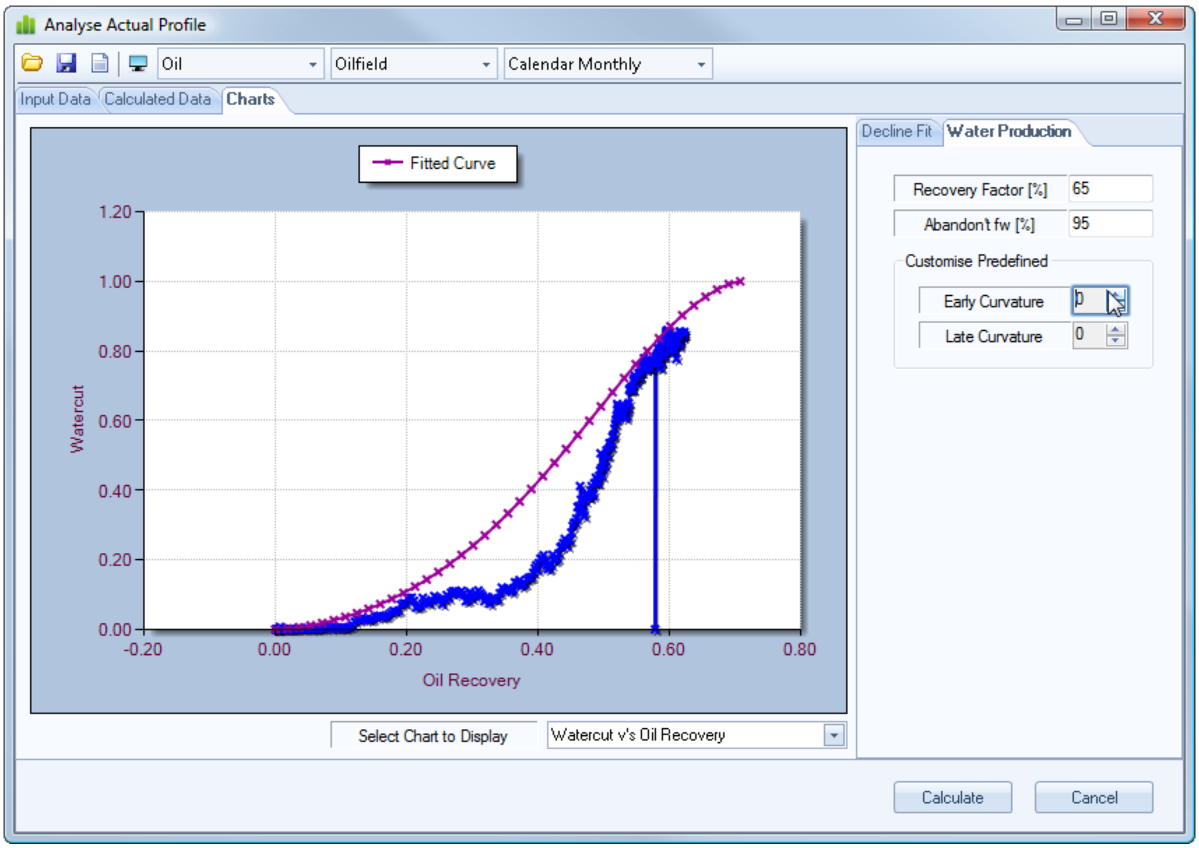
The following task pane will then be populated with decline exponents, see below. The user can toggle between decline types and whether or not to fix the initial selected rate in the regression analysis. The user should manually iterate between these options until the RMS error is minimised.



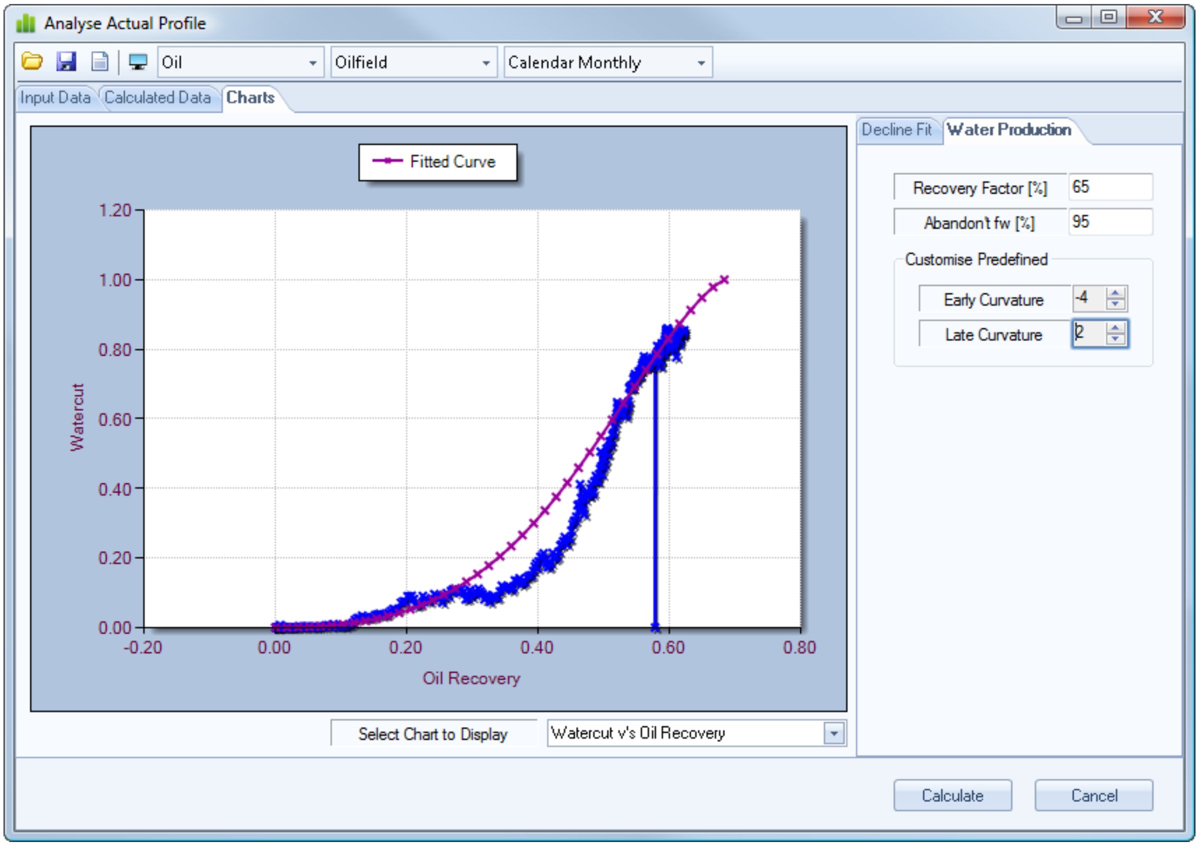


Should the User wish to extrapolate an ultimate recovery and abandonment date, simply enter an abandonment rate in the above text box "Qa" and press the *Predict* button.

The user can also manually regress a watercut Vs oil recovery relationship, by selecting the "Watercut Vs Oil Recovery" chart and expanding the *Water Production* navigation bar category.



Once the user has entered approximate numbers for *Recovery Factor* and *Abandonment Watercut (fw)*, the User can iterate the Early and Late curvature values, as shown below, until a satisfactory fit is achieved.



For completeness, the ultimate recovery and abandonment date equations are included below.

Where,

- qa = Abandonment production rate
- qi = Initial production rate
- a = Constant decline rate fraction, between 0 and 1
- n = additional constant decline exponent, between 0 and 1
- Npa = Cumulative Production between qi and qa
- Ta = Time (in days) between qi and qa

Exponential Decline

$$N_{pa} = \frac{1}{a} \times (q_i - q_a) \qquad T_a = \frac{\ln\left(\frac{q_a}{q_i}\right)}{-a}$$

Harmonic Decline

$$N_{pa} = \frac{q_i}{a} \times \ln\left(\frac{q_i}{q_a}\right) \qquad T_a = \frac{\left(\frac{q_a}{q_i} - 1\right)}{a}$$

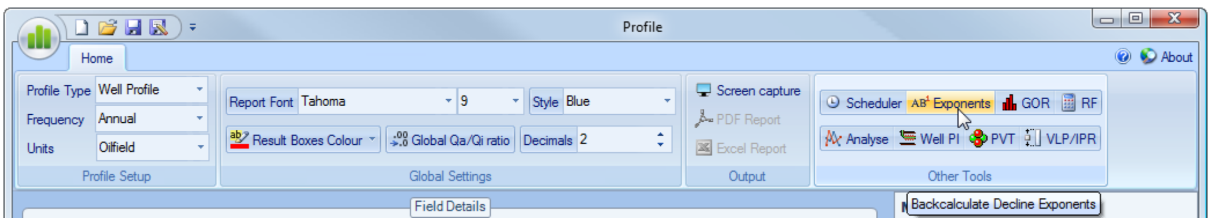
Hyperbolic Decline

$$N_{pa} = \frac{q_i}{(1-n)\times a} \times \left(1 - \left(\frac{q_i}{q_a}\right)^{(1-n)}\right)$$

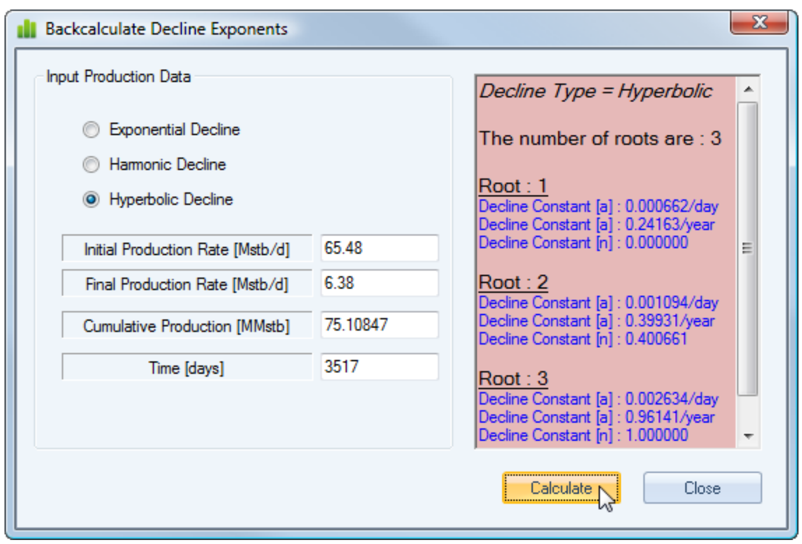
$$T_a = \frac{\left[\frac{\left(\left(q_i / q_a\right)^n - 1\right)}{n}\right]}{a}$$

12.3 Backcalculate Decline Exponents

The following tool is provided to allow the user to quickly calculate the decline curve exponents having minimal knowledge of the production history.



Once the tool is selected, the following input form should be displayed.



Both the exponential and harmonic decline curve equations are special cases of the hyperbolic decline curve equation. The exponential equation has a value of 'n'=0, and harmonic equation has a value of 'n'=1, in the hyperbolic decline curve equation.

For both the exponential and harmonic decline curves, the exponent 'a' can be solved by re- arranging their decline curve equations to the following :

Exponential Equation Harmonic Equation

$$a = \frac{\ln\left(\frac{q_i}{q}\right)}{t} \qquad\qquad a = \frac{\left(\frac{q_i}{q} - 1\right)}{t}$$

From the above equations, the user should note that only a knowledge of the initial production rate, final production rate and time interval are required to calculate the decline exponent 'a'.

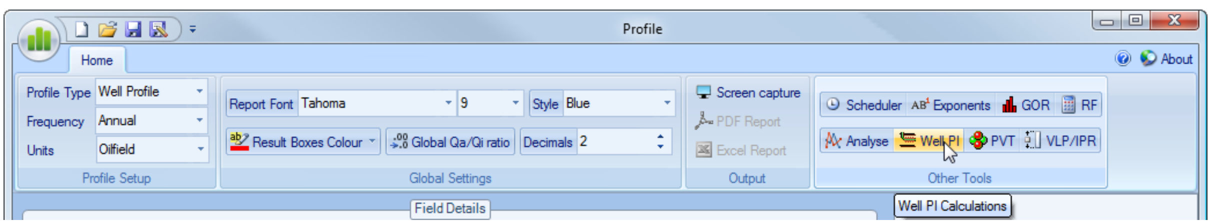
The solution of the hyperbolic parameters are based on the technique described in the following Society of Petroleum Engineers paper, where an additional parameter Cumulative production, Np, is required.

"A Numerical Solution to Two-Parameter Representation of Production Decline Curve Analysis", SPE16505, B. Agbi and M Ng, 1987

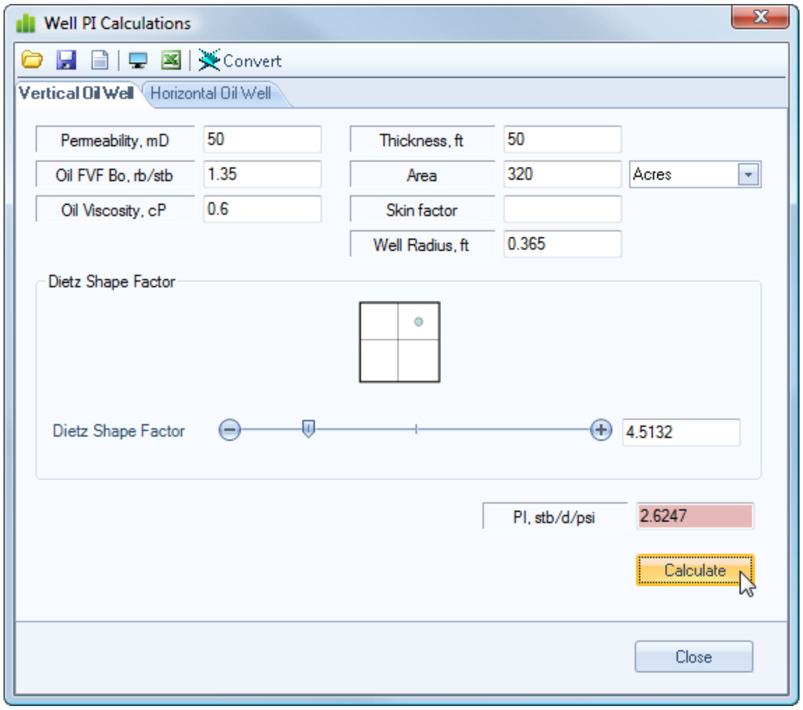
The solution of the hyperbolic decline curve equation for values of 'a' and 'n' displays all roots of the equation, including values of 'a' at n=0 (exponential decline) and n=1 (harmonic decline).

12.4 Well PI Calculations

The following tool is provided to allow the user to quickly, but approximately, estimate the well productivity index (PI) of a vertical or horizontal oil well.



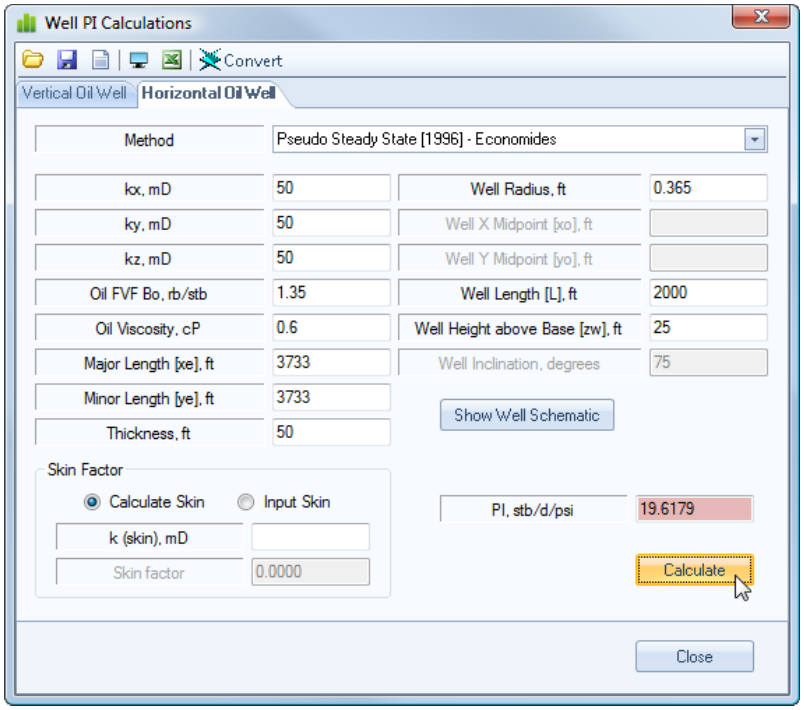
Once the tool is selected, the following input form should be displayed.



The user can easily change the Dietz shape factor contained within the semi/pseudo steady- state vertical PI equation, by using the track bar located in the Dietz Shape Factor group box. A graphical image of individual shapes and their respective shape factor values are displayed simultaneously as the user slides the track bar.

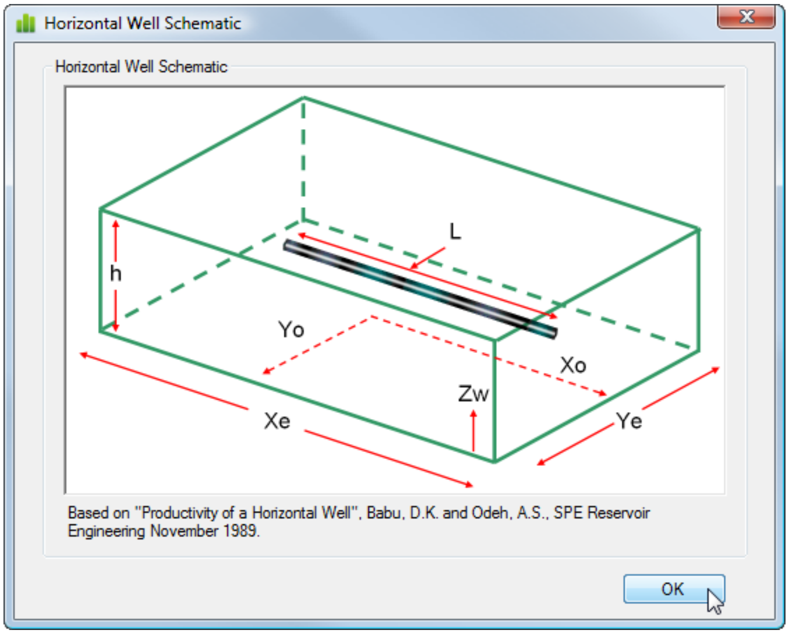
Once the user has input all the necessary input, select the Calculate button to calculate the vertical semi/pseudo steady state PI.

Horizontal and slanted oil well PI can be calculated in the second tab Horizontal Oil Well.

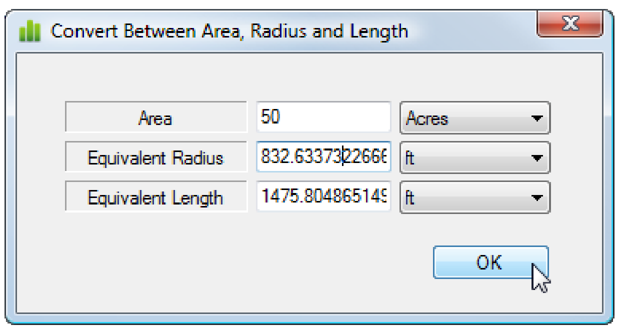


The user can select from numerous published techniques, listed below :

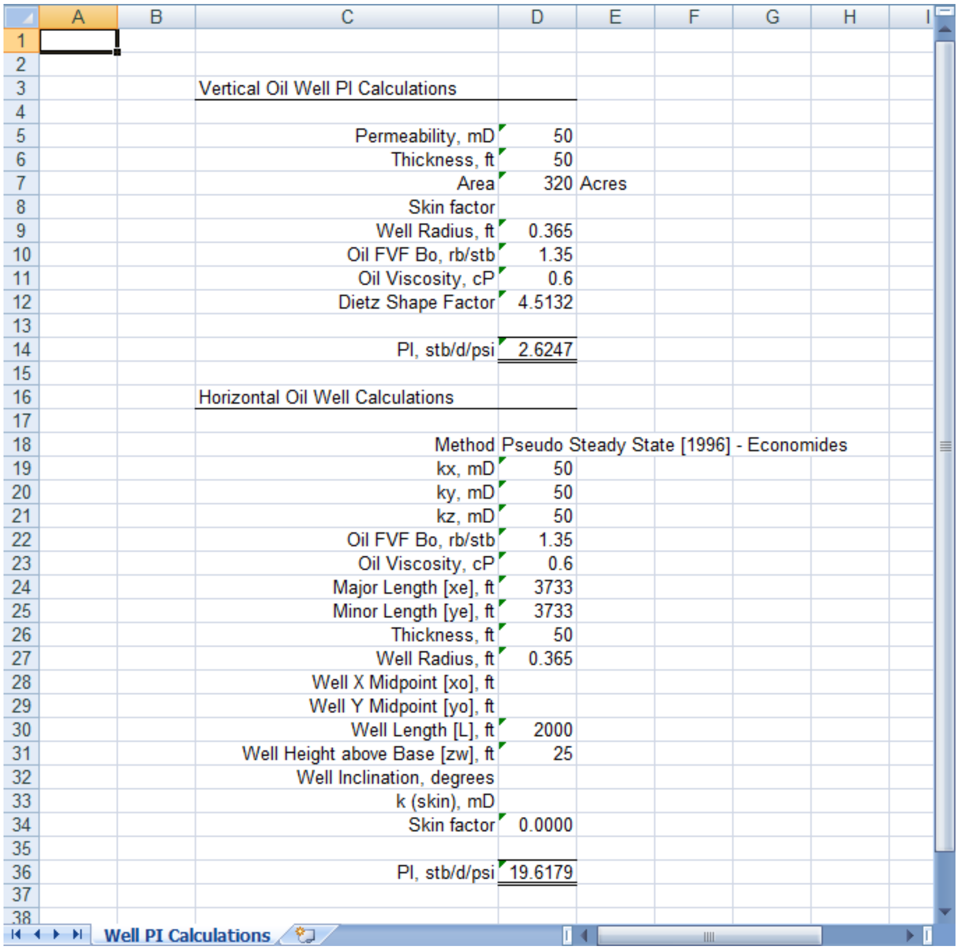
A well schematic is included within the application (and accessed by selecting the Show Well Schematic button) to clarify the various nomenclature requested. The schematic is shown for completeness below.



Another tool is provided to allow the user to quickly convert between area, equivalent radius and length, to better permit comparison with vertical and horizontal PI solutions. To convert between area, radius and length simply type a number into one of the text boxes and then leave the text box (select tab or mouse click to go to another text box).



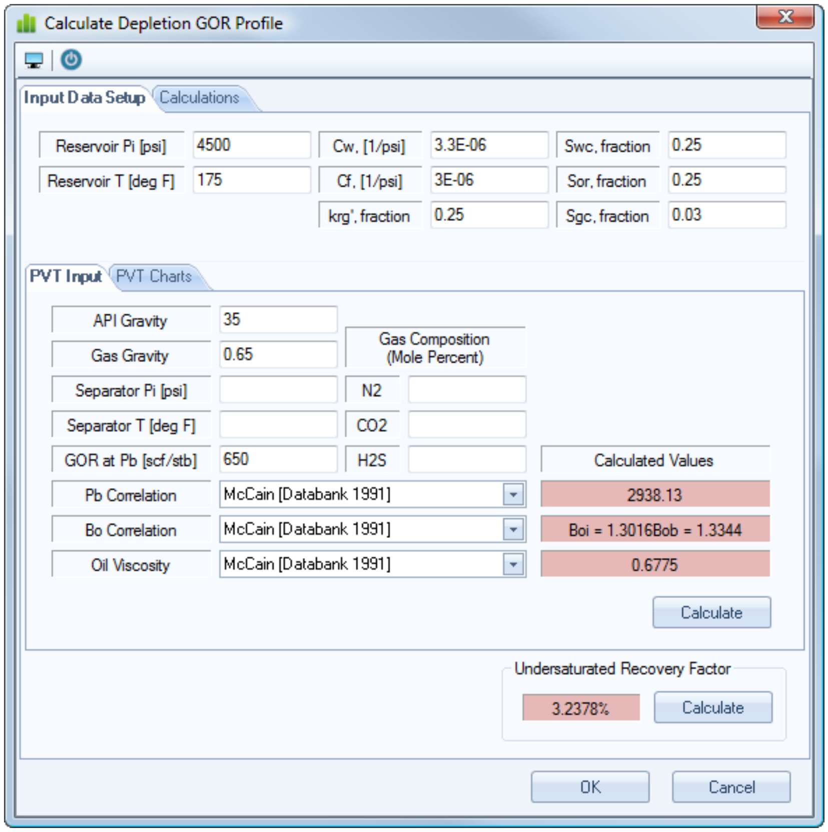
The user can generate a Microsoft Excel report by selecting Excel icon in the toolbar located towards the top of the dialog form. The user will be prompted for an Excel filename, and a file similar to one the following should be created.



Vertical Oil Well PI Calculations		
Permeability, mD	50	
Thickness, ft	50	
Area	320	Acres
Skin factor		
Well Radius, ft	0.365	
Oil FVF Bo, rb/stb	1.35	
Oil Viscosity, cP	0.6	
Dietz Shape Factor	4.5132	
PI, stb/d/psi	2.6247	
Horizontal Oil Well Calculations		
Method	Pseudo Steady State [1996] - Economides	
kx, mD	50	
ky, mD	50	
kz, mD	50	
Oil FVF Bo, rb/stb	1.35	
Oil Viscosity, cP	0.6	
Major Length [xe], ft	3733	
Minor Length [ye], ft	3733	
Thickness, ft	50	
Well Radius, ft	0.365	
Well X Midpoint [xo], ft		
Well Y Midpoint [yo], ft		
Well Length [L], ft	2000	
Well Height above Base [zw], ft	25	
Well Inclination, degrees		
k (skin), mD		
Skin factor	0.0000	
PI, stb/d/psi	19.6179	

12.5 Calculate Depletion GOR Profile

The material balance depletion method tool is provided for oilfields to calculate the primary depletion gas production, and is entirely based on the technique outlined by Laurie Dake in "The Practice of Reservoir Engineering", published by Elsevier. [Chapter 3.7 - Volumetric Depletion Fields].



The tool has two main sections accessed from the toolbar; *Input Data Setup* and *Calculations*.

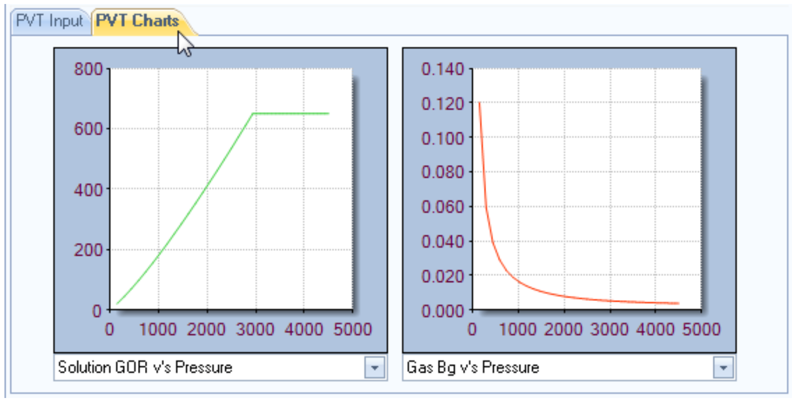
Input Data Setup Panel

Within the *Input Data Setup* tab (shown above), the user is asked to input the initial reservoir pressure, reservoir temperature, water and formation compressibility, endpoint gas relative permeability, initial water, residual oil and critical gas saturation values.

The user is also asked to input Fluid PVT values of API gravity, gas gravity, GOR at bubblepoint pressure and any CO2 and H2S content in the gas composition.

Once the PVT data has been input the user can press the *Calculate* button in the PVT Input tab and values for bubblepoint pressure (Pb), oil formation volume factor (Bo) and oil viscosity, will be displayed for the selected correlation.

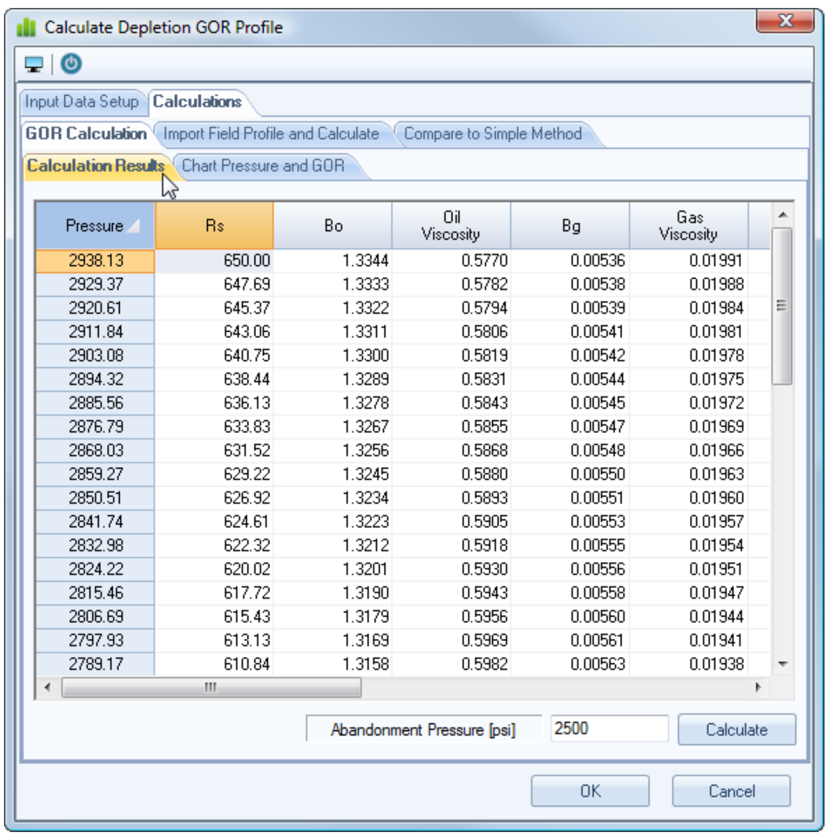
To view the calculated values of Oil GOR, Bo and viscosity versus pressure and Gas Bg, Viscosity and Z Factor versus pressure select the PVT Charts tab, as shown below.



Once the user is happy with the input data and PVT calculations, to calculate the Undersaturated recovery factor simply press the Calculate button in the Undersaturated Recovery Factor Group box, located at the bottom of the *Input Data Setup* Panel.

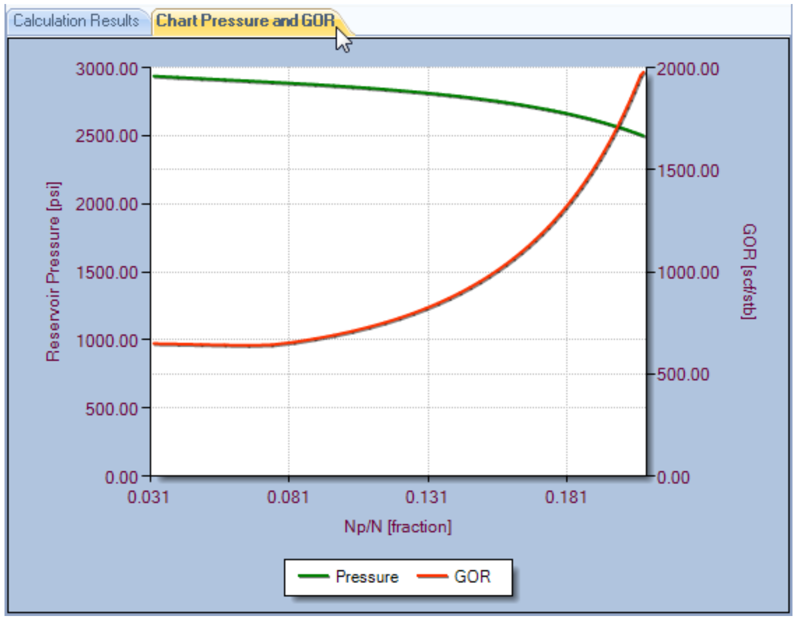
Calculations Panel

Once the user presses the *Calculations* tab, the following panel is displayed.

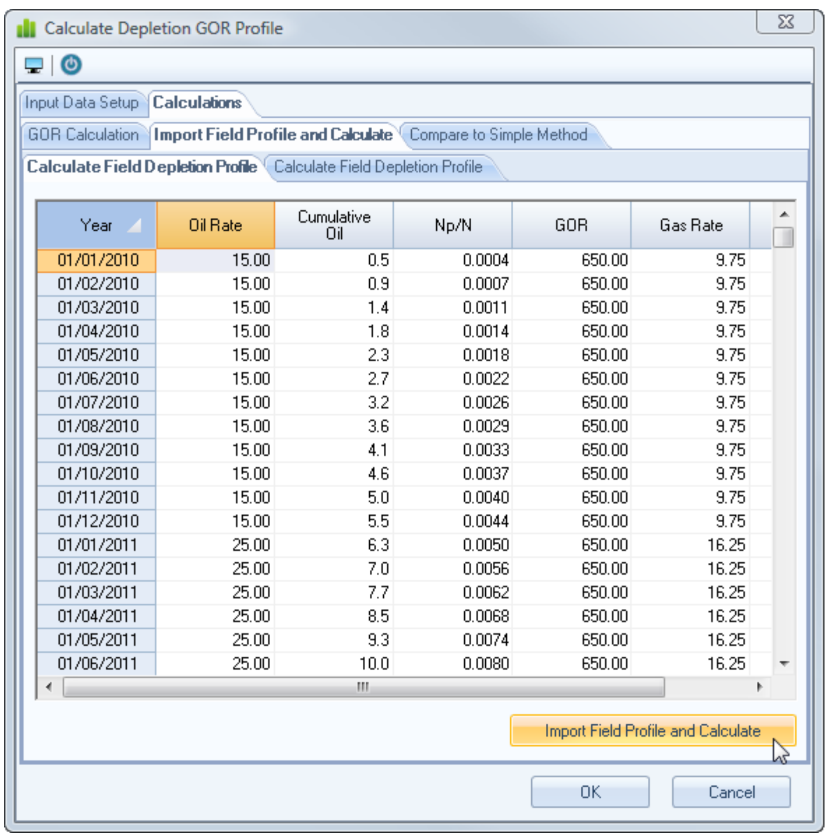


Once the user enters a valid abandonment pressure and presses the Calculate button, the Muskat technique (as outlined by Dake) for calculating depletion below the bubblepoint is performed.

A chart showing the pressure and GOR behaviour is shown in the *Chart Pressure and GOR* tab, and an example is shown below.



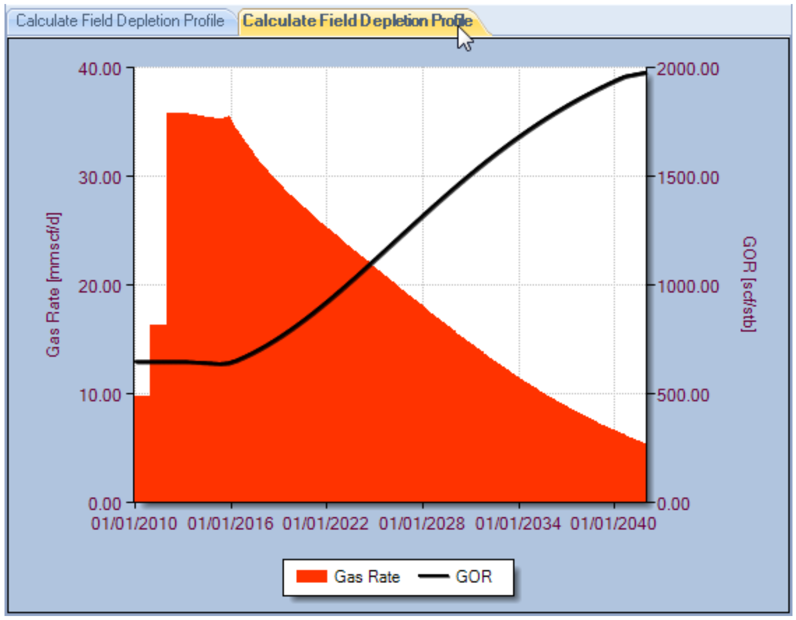
Once the user is happy with the pressure and GOR behaviour, they can proceed by pressing the *Import Field Profile and Calculate* button located towards the top of the *Calculations* panel, and the following will be displayed.



Year	Oil Rate	Cumulative Oil	Np/N	GOR	Gas Rate
01/01/2010	15.00	0.5	0.0004	650.00	9.75
01/02/2010	15.00	0.9	0.0007	650.00	9.75
01/03/2010	15.00	1.4	0.0011	650.00	9.75
01/04/2010	15.00	1.8	0.0014	650.00	9.75
01/05/2010	15.00	2.3	0.0018	650.00	9.75
01/06/2010	15.00	2.7	0.0022	650.00	9.75
01/07/2010	15.00	3.2	0.0026	650.00	9.75
01/08/2010	15.00	3.6	0.0029	650.00	9.75
01/09/2010	15.00	4.1	0.0033	650.00	9.75
01/10/2010	15.00	4.6	0.0037	650.00	9.75
01/11/2010	15.00	5.0	0.0040	650.00	9.75
01/12/2010	15.00	5.5	0.0044	650.00	9.75
01/01/2011	25.00	6.3	0.0050	650.00	16.25
01/02/2011	25.00	7.0	0.0056	650.00	16.25
01/03/2011	25.00	7.7	0.0062	650.00	16.25
01/04/2011	25.00	8.5	0.0068	650.00	16.25
01/05/2011	25.00	9.3	0.0074	650.00	16.25
01/06/2011	25.00	10.0	0.0080	650.00	16.25

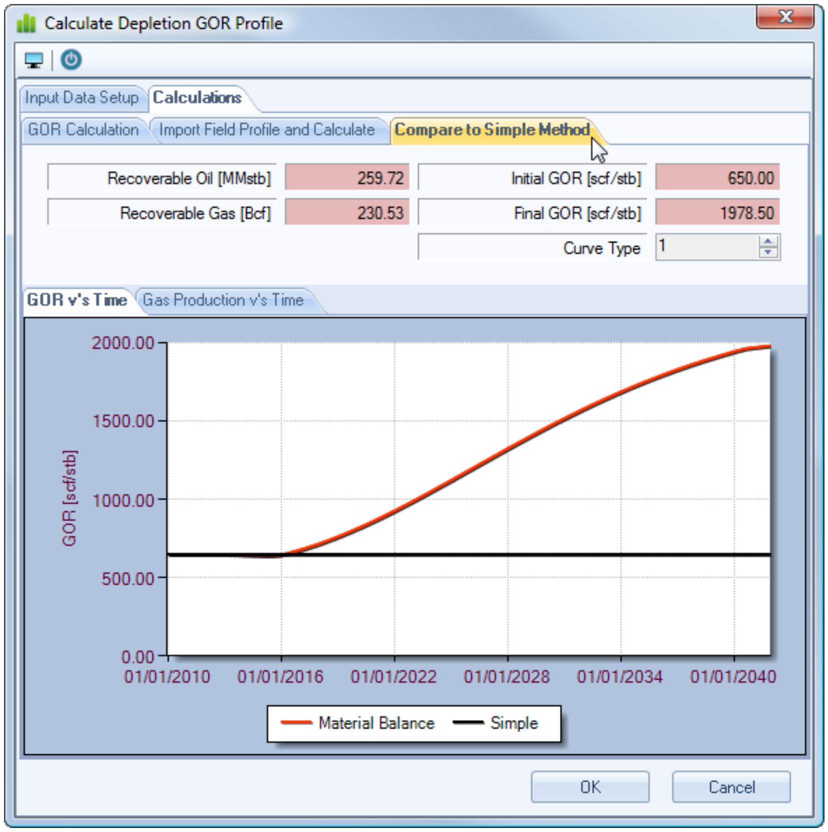
The user should press the *Import Field Profile and Calculate* button to import the primary oil production profile and calculate the gas profile based on the Muskat calculated GOR profile.

The Gas production rate and GOR profile can be viewed by selecting the Chart Pressure and GOR tab, as shown below.



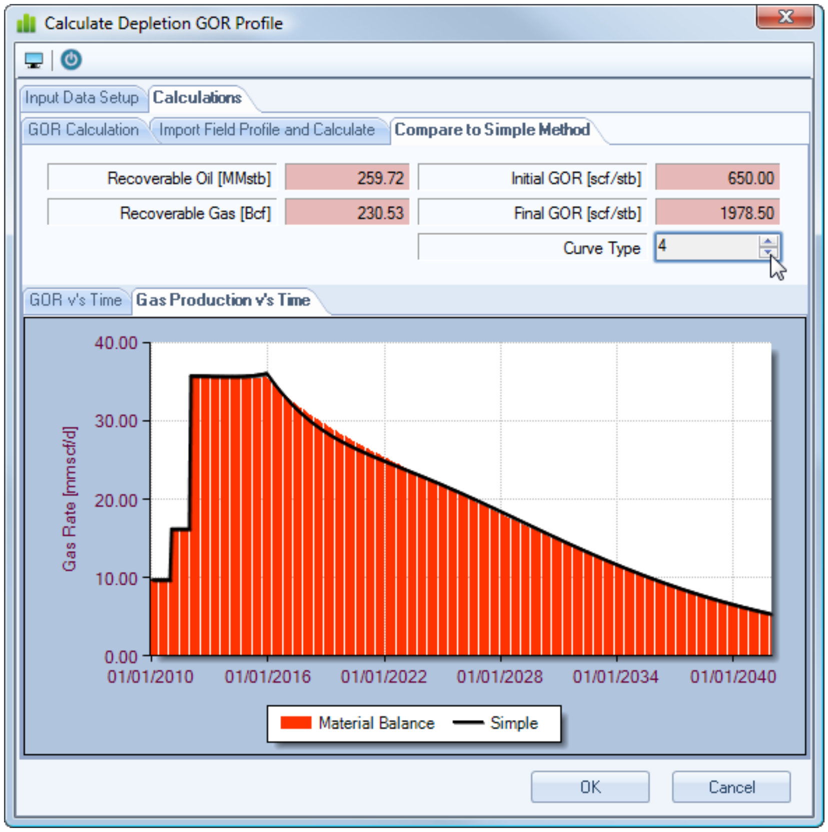
To compare the Material Balance calculated profile with the Simple Method Profile, select the *Compare to Simple Method* button, located towards the top of the *Calculations* panel.

The following will be displayed.



All numbers are fixed in this panel with the exception of the *Curve Type*. The user can toggle the value of Curve Type [between 1 and 10] by selecting the up and down arrows in the Curve Type value box.

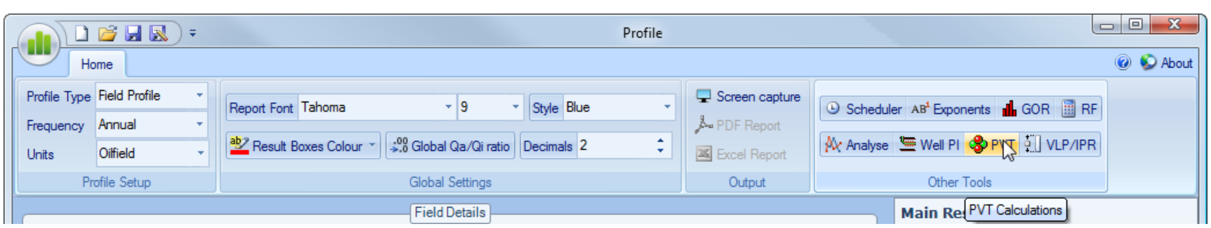
To view the Gas Production profile comparison simply select the Gas Production Vs Time tab, as shown below.



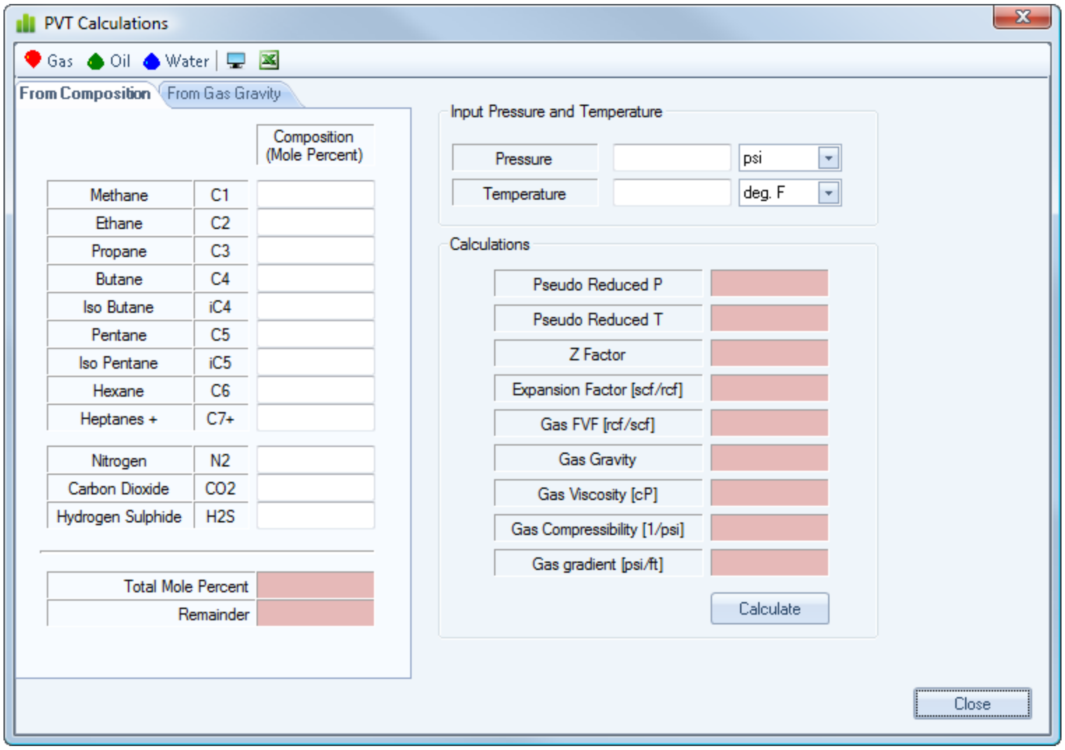
To transfer the calculated material balance values back into the main application's Associated Production Use Simple Method technique, the user should press the *OK* button. To return to the main application without transferring any values, the User should press the *Cancel* button.

12.6 PVT Calculations

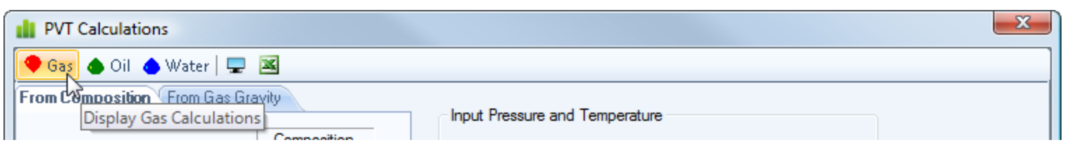
The following tool is provided to allow the user to quickly calculate values for Gas, oil and water fluid properties.



Once the tool is selected, the following input form should be displayed.



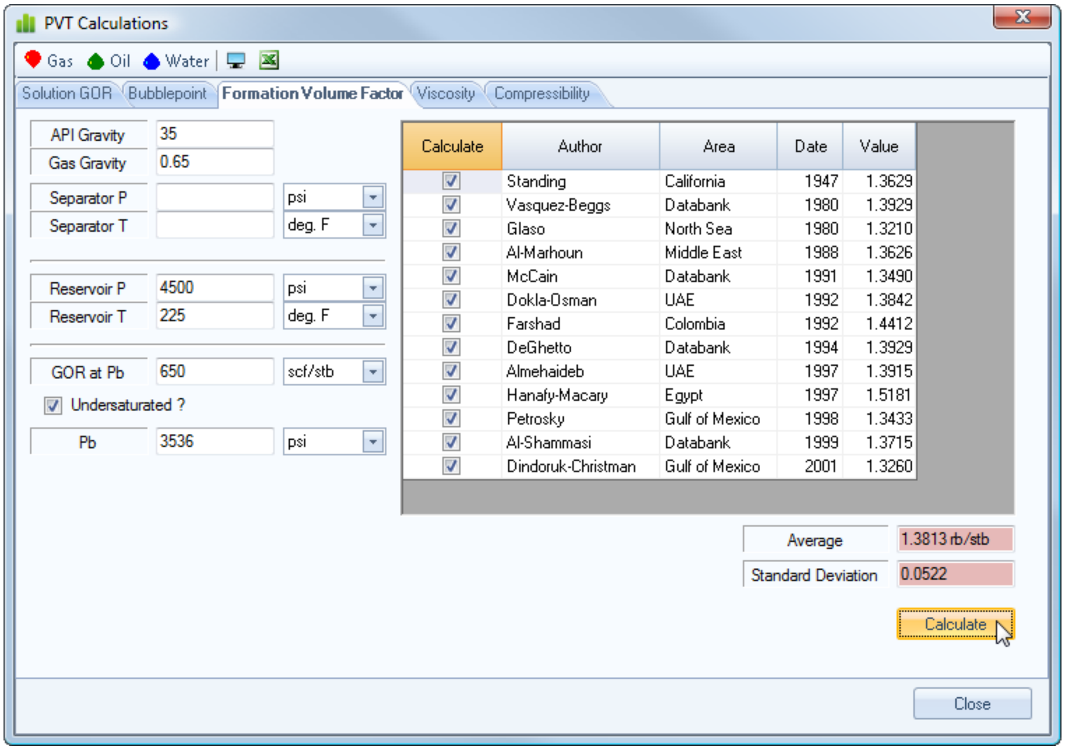
The user can select between Gas, Oil and Water calculations by pressing the icons in the toolbar, as shown below.



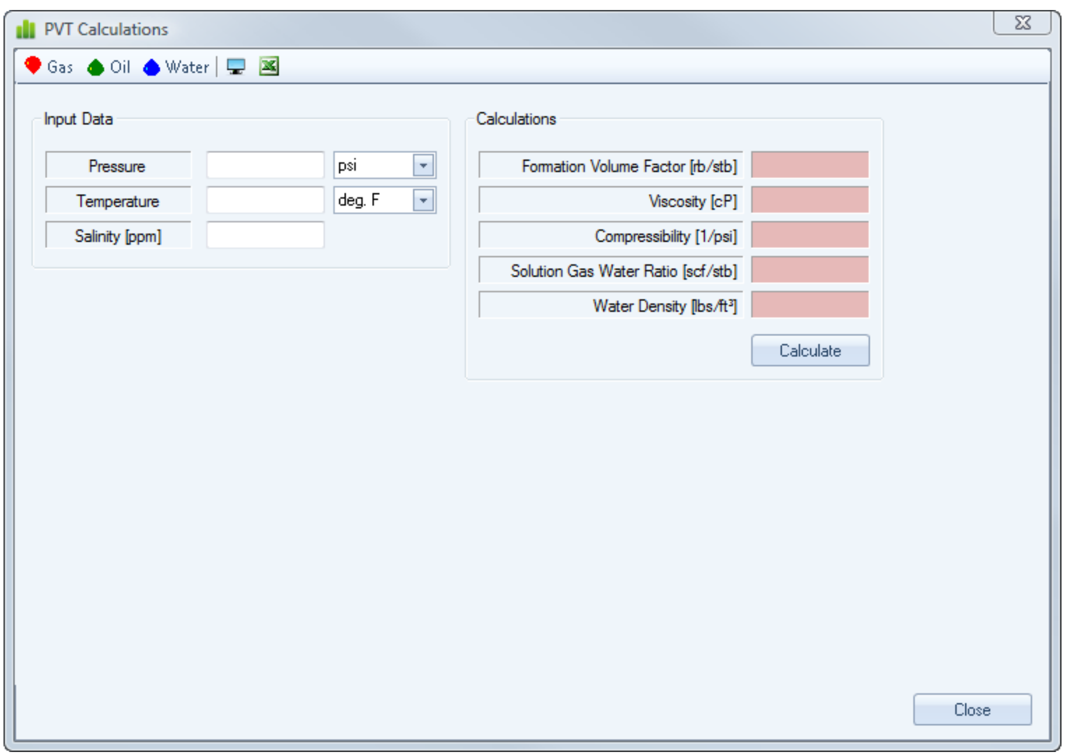
Within the Gas PVT Calculations panel, the user can choose to calculate the relevant PVT properties based on a knowledge of the gas composition or the gas gravity.

The Oil PVT Calculations panel is shown below and consists of numerous published correlations for solution GOR, bubblepoint, formation volume factor, viscosity and compressibility.

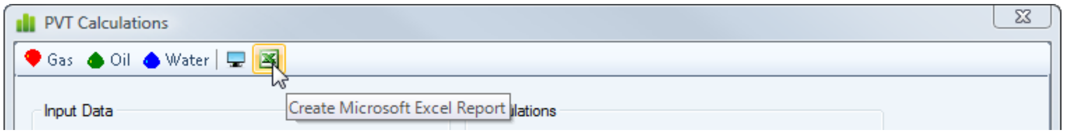
Once all the required data has been input and the user presses the Calculate button, the list of correlation results are displayed. To enable or disable a correlation value from the average and standard deviation results at the bottom, simply un-check the correlation and re-press the Calculate button.



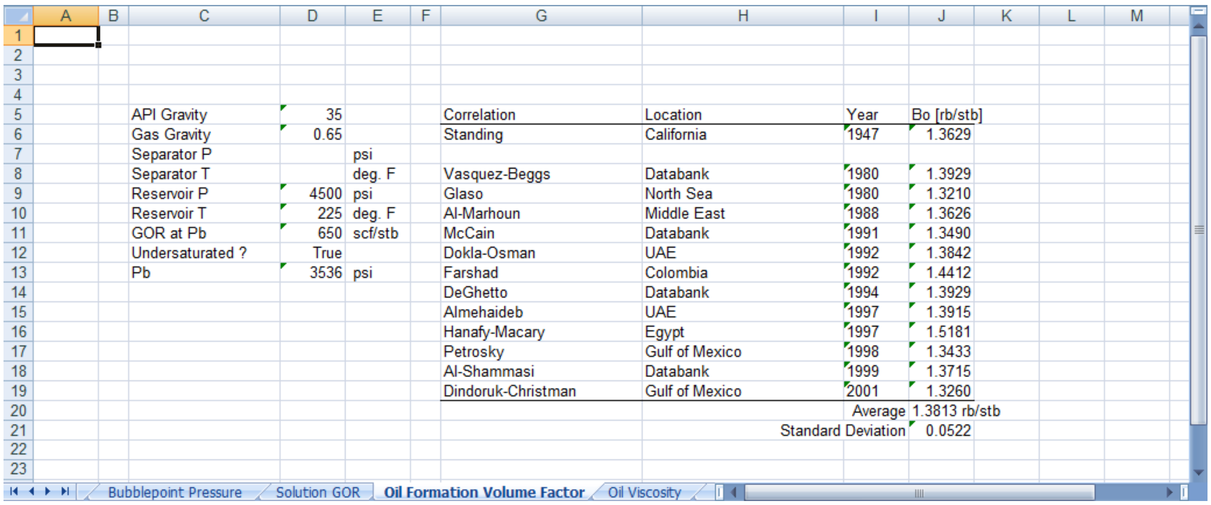
The Water PVT Calculations panel is shown below



The user can generate a Microsoft Excel report by selecting the Excel icon in the toolbar, as shown below.



The user will be prompted for a report XLS filename, and a file similar to the following should be created.

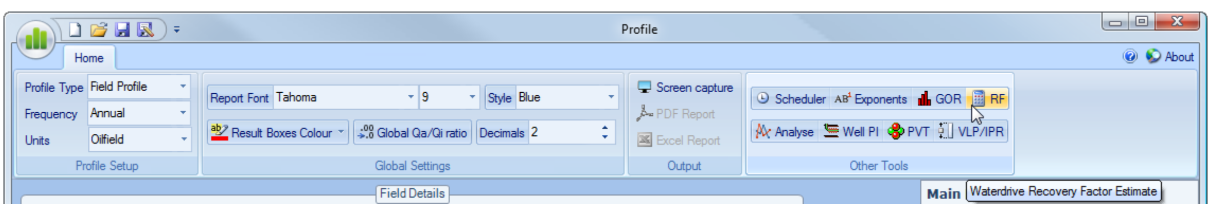


API Gravity	35		Correlation	Location	Year	Bo [rb/stb]
Gas Gravity	0.65		Standing	California	1947	1.3629
Separator P		psi				
Separator T		deg. F	Vasquez-Beggs	Databank	1980	1.3929
Reservoir P	4500	psi	Glaso	North Sea	1980	1.3210
Reservoir T	225	deg. F	Al-Marhoun	Middle East	1988	1.3626
GOR at Pb	650	scf/stb	McCain	Databank	1991	1.3490
Undersaturated ?	True		Dokla-Osman	UAE	1992	1.3842
Pb	3536	psi	Farshad	Colombia	1992	1.4412
			DeGhetto	Databank	1994	1.3929
			Almehaideb	UAE	1997	1.3915
			Hanafy-Macary	Egypt	1997	1.5181
			Petrosky	Gulf of Mexico	1998	1.3433
			Al-Shammasi	Databank	1999	1.3715
			Dindoruk-Christman	Gulf of Mexico	2001	1.3260
					Average	1.3813 rb/stb
					Standard Deviation	0.0522

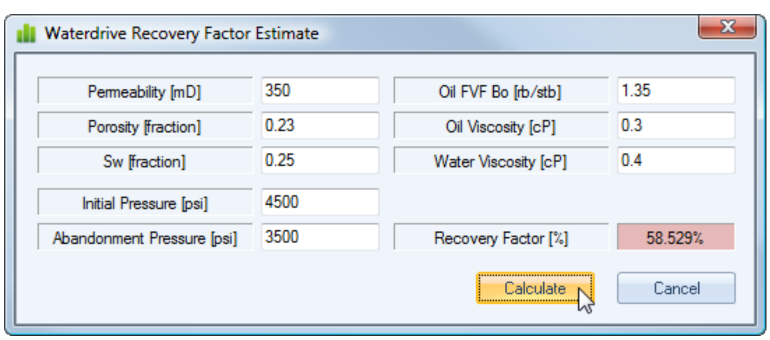
12.7 Recovery Factor Estimate

The following tool is provided to allow the user to quickly calculate a waterdrive recovery factor for potential use with the Associated Water Production ultimate field recovery factor.

The routine for calculation of recovery factor is based on the equation developed by the American Petroleum Institute (API) "A Statistical Study of Recovery Efficiency", 1967.



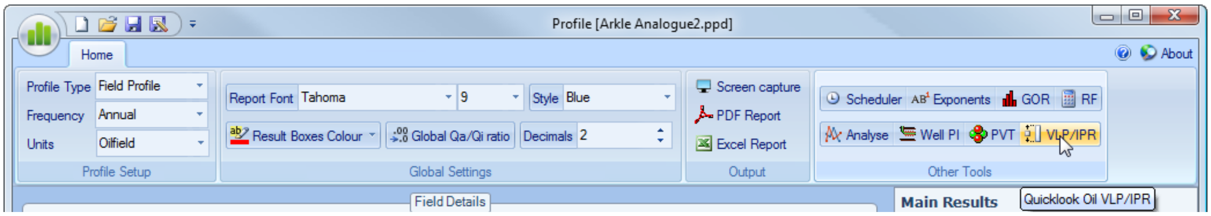
Once the tool is selected, the following input form should be displayed.



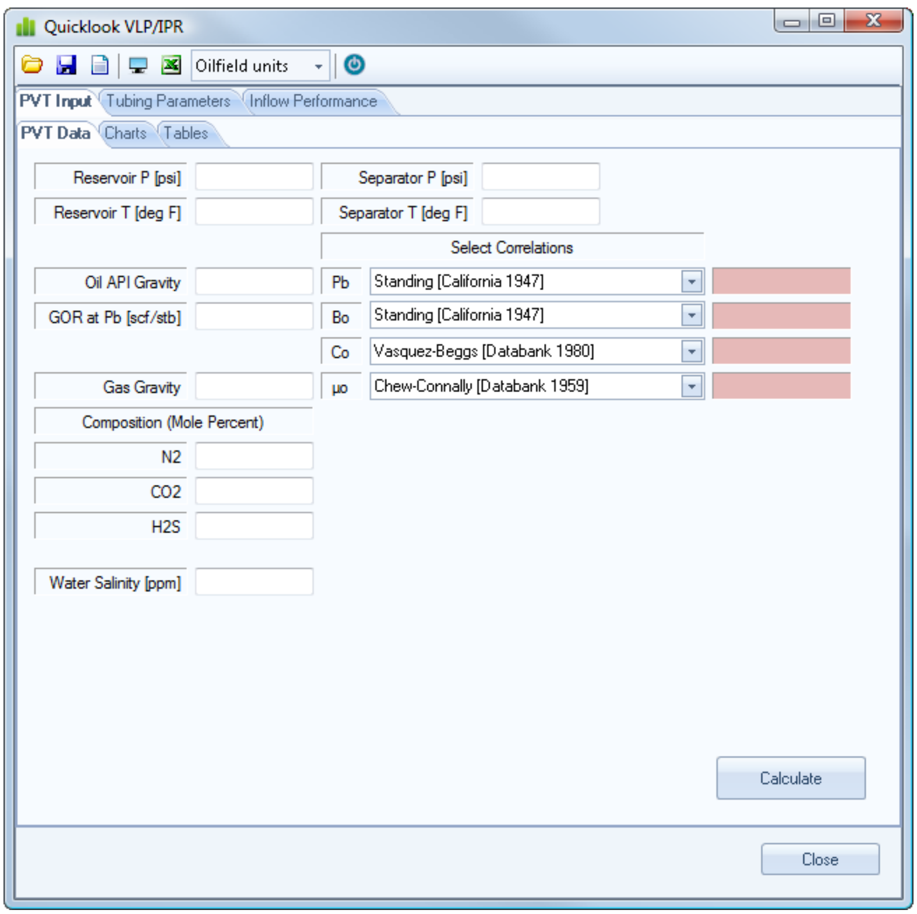
The user should enter all the required data, then press the calculate button. To return to main application select the OK button.

12.8 Quicklook Oil VLP/IPR

The following tool is provided to allow the user to quickly calculate, from nodal analysis, the likely initial well oil production rate given a specific tubing design and well trajectory.



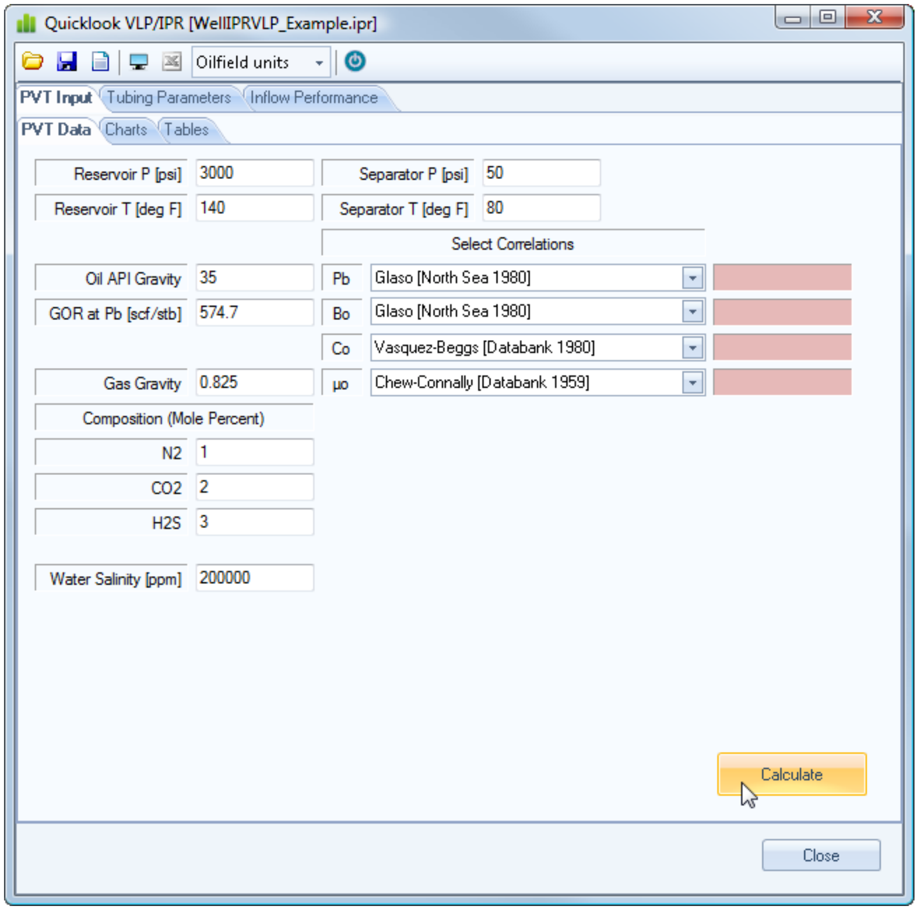
Once the tool is selected, the following input form should be displayed.



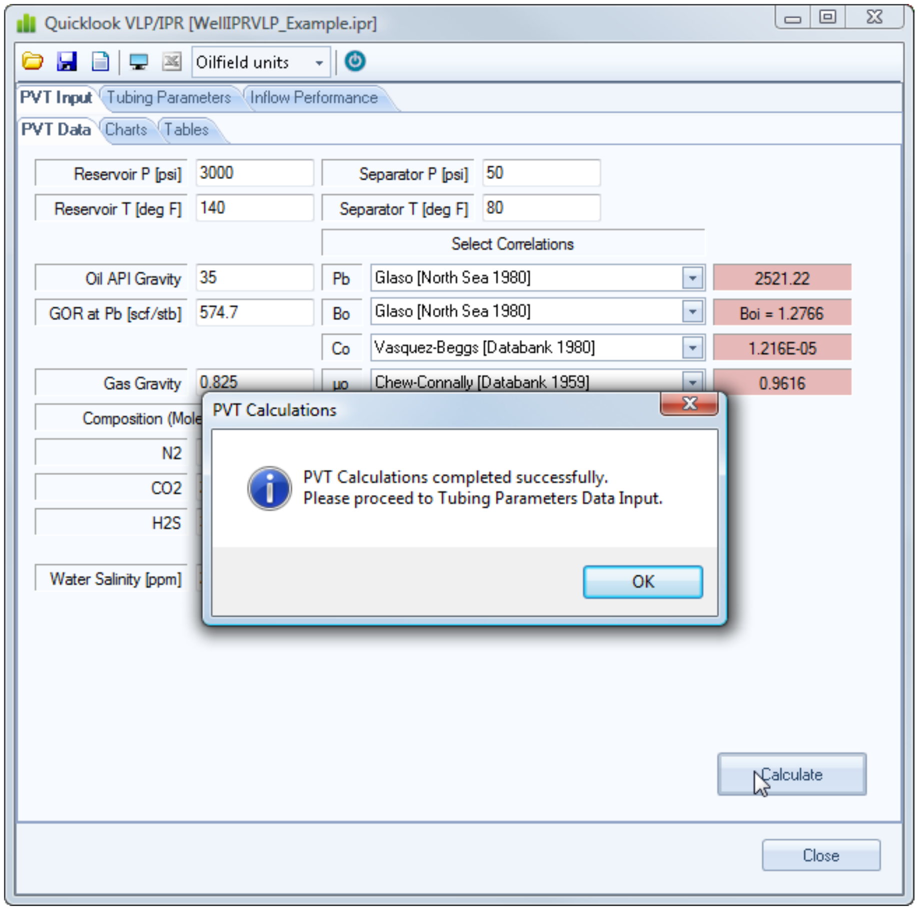
The input data sections are split into three distinct areas and the data and calculations must be input in a sequential manner, as illustrated below.

1. PVT Data Input

Firstly the PVT data has to be input, as shown below.



Once the user has entered all the necessary PVT data, then the user should select the ***Calculate*** button as shown above. Assuming all the data is correct then the following should be displayed.

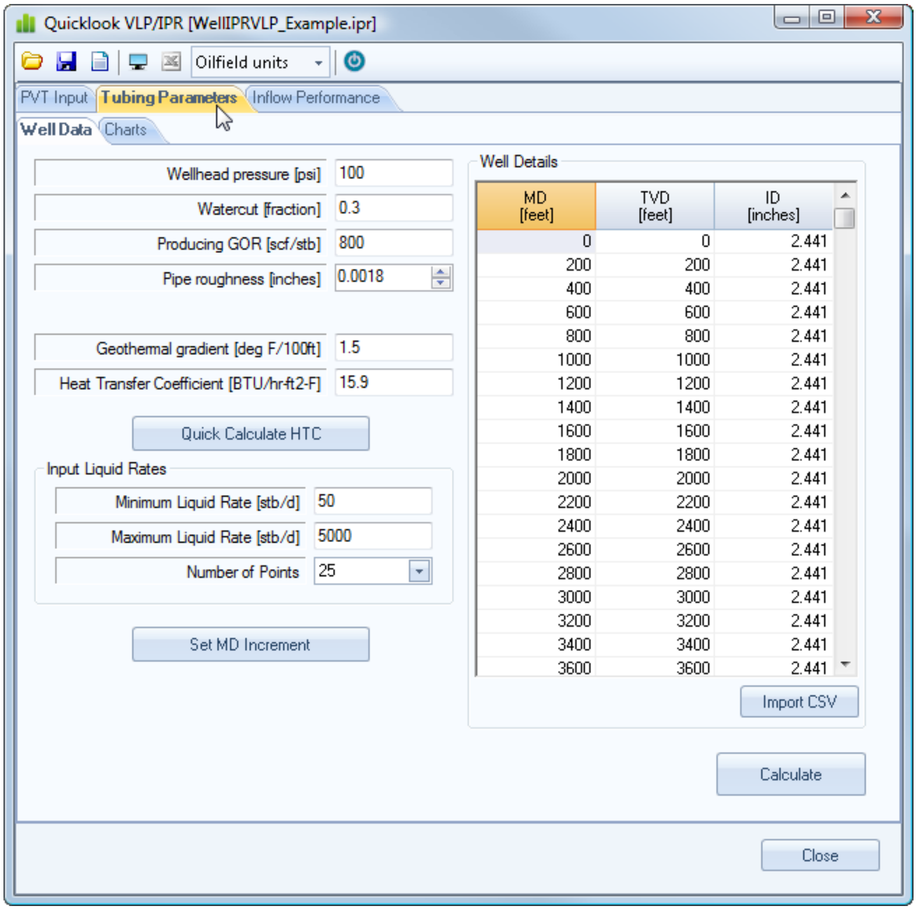


Charts and tables of PVT results can be inspected in the Charts and Tables section of the PVT input tabs.

Once the user is satisfied with the PVT input and calculations they should proceed to the ***Tubing Parameters*** Main tab in order to input the required data in this section.

2. Tubing Parameters

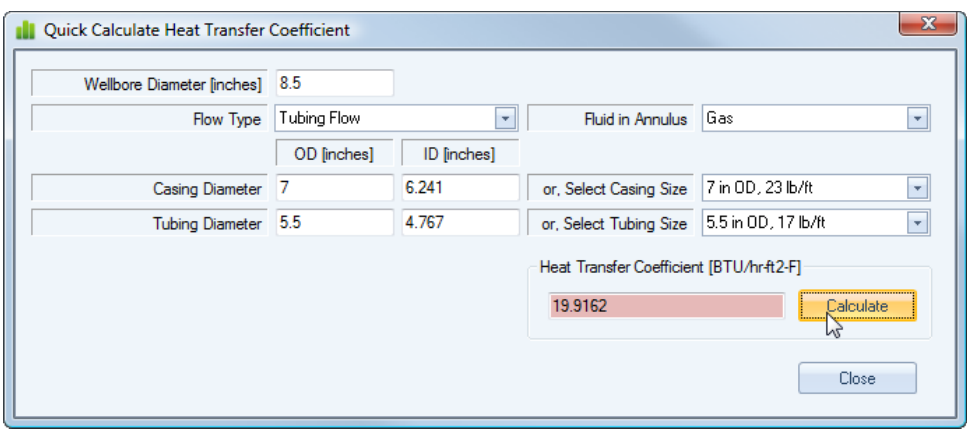
In this section, the user should well trajectory and tubing ID as a function of Measured Depth [MD] Vs True Vertical Depth [TVD], as well as other well properties in order to calculate the vertical lift performance via nodal analysis. For information, the method used within this routine is the Modified Hagedorn and Brown multi-phase vertical lift performance relationship.



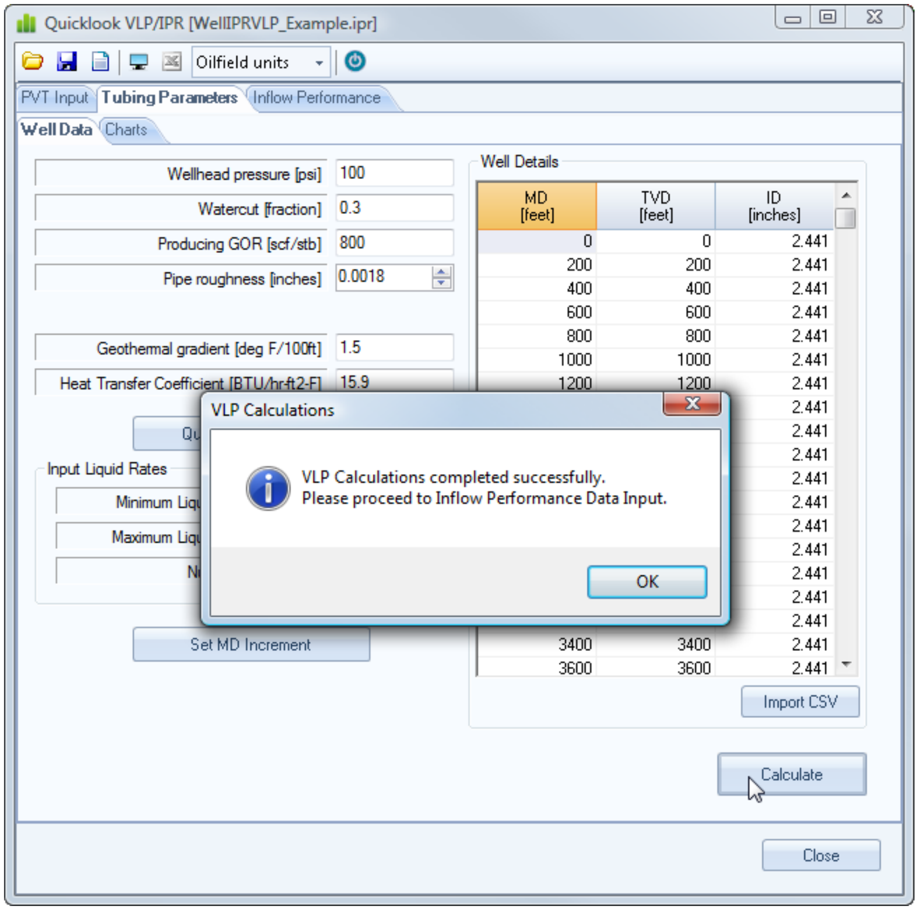
MD [feet]	TVD [feet]	ID [inches]
0	0	2.441
200	200	2.441
400	400	2.441
600	600	2.441
800	800	2.441
1000	1000	2.441
1200	1200	2.441
1400	1400	2.441
1600	1600	2.441
1800	1800	2.441
2000	2000	2.441
2200	2200	2.441
2400	2400	2.441
2600	2600	2.441
2800	2800	2.441
3000	3000	2.441
3200	3200	2.441
3400	3400	2.441
3600	3600	2.441

One of the main uncertainties with any vertical lift performance relationship is what value should the user assume for the heat transfer coefficient [HTC] between the tubing and the rock formation along the total length of the wellbore, assuming no knowledge of producing temperatures from offset wells. As a ready reckoner, the user is provided with a quick HTC calculator, which is shown below.

With this ready reckoner, the user can quickly iterate for given well configurations for likely values of HTC, for use with the vertical lift analysis.



Once the user is satisfied with the input of well tubing parameters, they should press the Calculate button as shown below, and the following screen should appear.



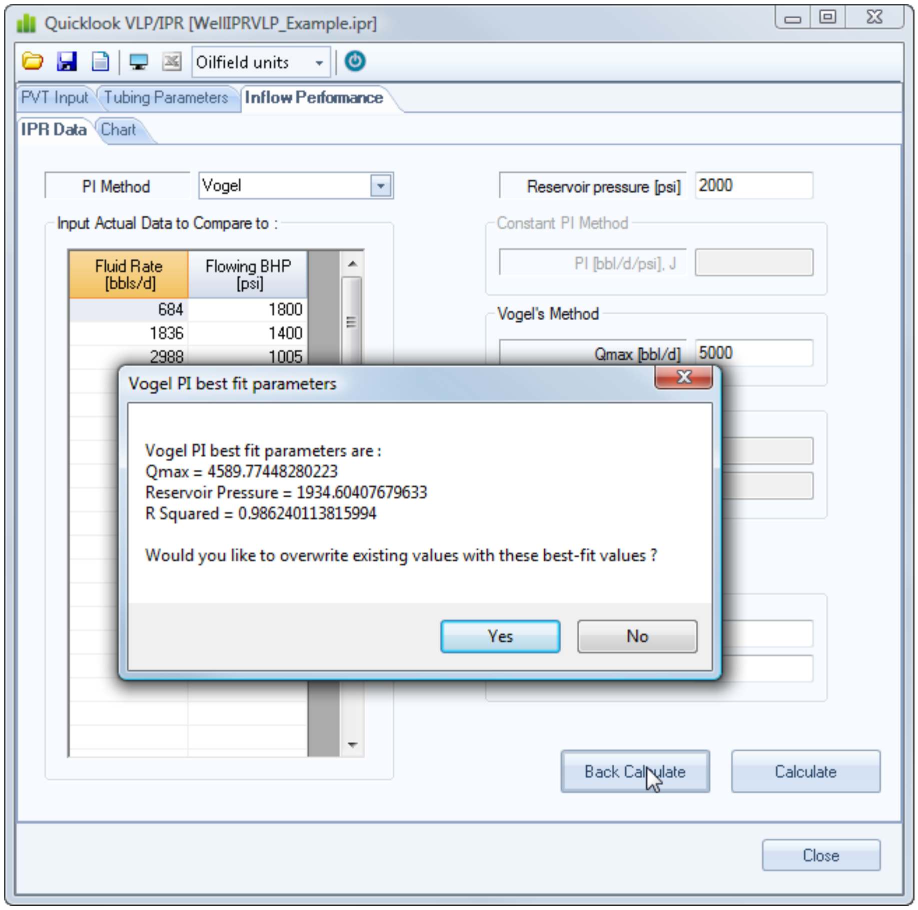
Charts of various tubing calculation results can be inspected in the Charts section of the Tubing Parameters input tabs.

Once the user is satisfied with the Tubing Parameters input and calculations they should proceed to the ***Inflow Performance*** Main tab in order to input the required data in this section.

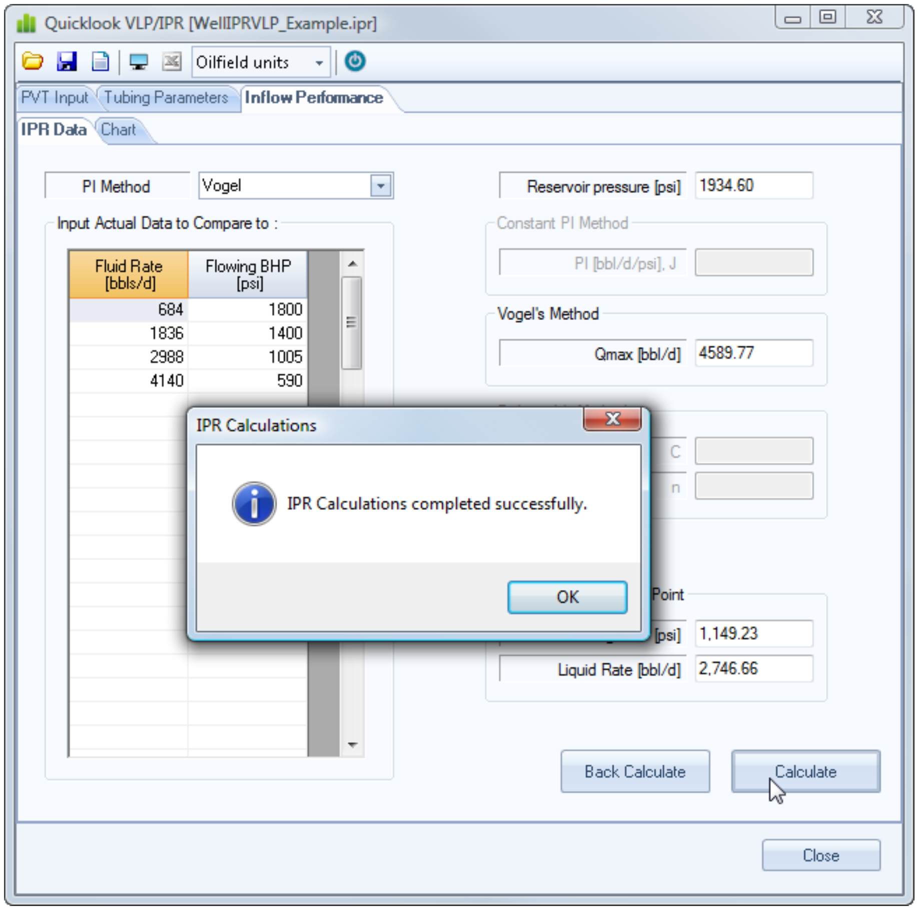
3. Inflow Performance

Within the Inflow Performance sections there are three methods for inputting and calculating Productivity Index, namely Constant PI, Vogel's or Fetkovich's method.

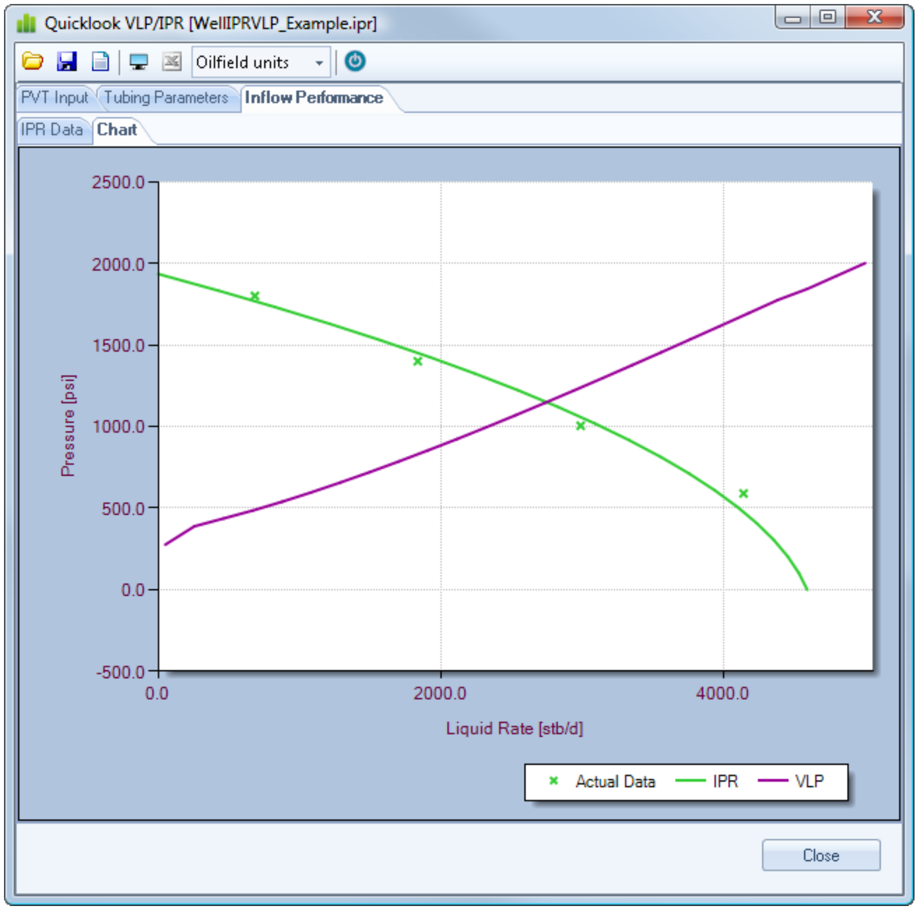
If the user has a knowledge of production liquids rate versus flowing bottom hole pressure [BHP] then the user can choose to back calculate and best fit any of the above method's input parameters. The example provided below is for the Vogel method. If the user selects the ***Yes*** button then the calculated values over write the original values in the input areas.



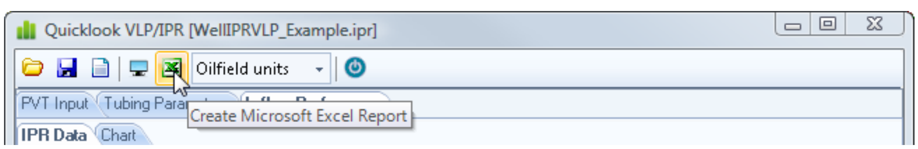
Once the user in satisfied with the input IPR values, they should press the ***Calculate*** button as shown below.



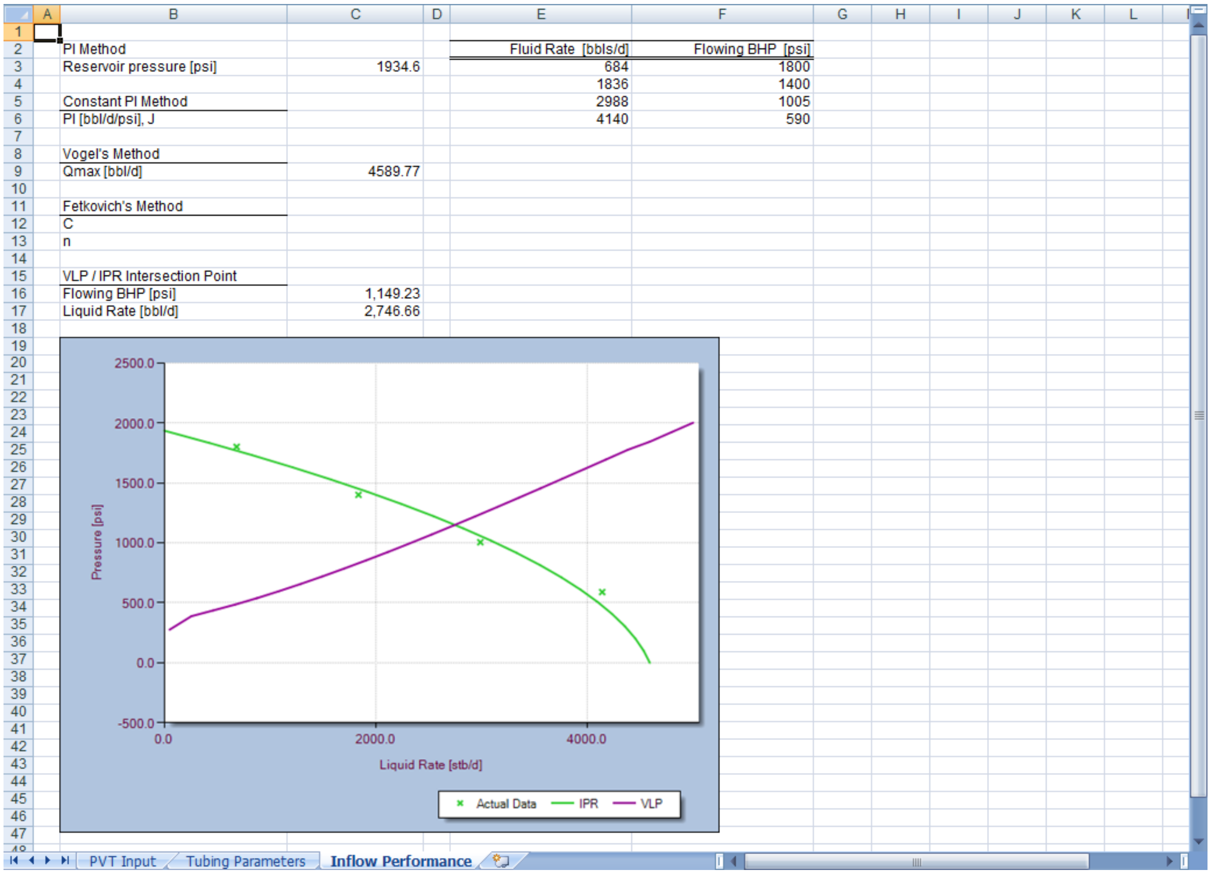
The routine will calculate the intersection point of the VLP and IPR relationships to give a resultant nodal analysis production rate and flowing bottom hole pressure.



The user can generate a Microsoft Excel report by selecting the Excel icon in the toolbar, as shown below.



The user will be prompted for a report XLS filename, and a file similar to the following should be created.


PI Method
Reservoir pressure [psi] 1934.6
Constant PI Method
PI [bbl/d/psi], J
Vogel's Method
Qmax [bbl/d] 4589.77
Fetkovich's Method
C
n
VLP / IPR Intersection Point
Flowing BHP [psi] 1,149.23
Liquid Rate [bbl/d] 2,746.66
Fluid Rate [bbls/d]
Flowing BHP [psi]
684 1800
1836 1400
2988 1005
4140 590
Pressure [psi]
Liquid Rate [stb/d]
Actual Data
IPR
VLP
PVT Input
Tubing Parameters
Inflow Performance

Profile

Production Profile Generation and Analysis

Part XIII

13 Worked Example

13.1 Arkle Discovery

Given the following reservoir information, calculate oil, gas and water production profiles and water injection, together with the associated facilities sizing (assuming 80% uptime) and schedule for well operations for the following West of the Hebrides discovery. *As is always, you have 1 hour to generate this forecast to then pass on to the economists !*

The preliminary prospect estimates and discovery data are shown below.

Summary Details

	Water depth [ft]	Field Type	STOOIP [mmstb]	Ultimate Recovery [mmstb]	Recovery Factor [%]
Arkle	1500	Oil	1200	360	30%

Volumetric and Reservoir Properties

	Reservoir Area [acres]	Reservoir Area [km^2]	Gross Thickness [feet]	Porosity [fraction]	Net-to-Gross ratio [fraction]	Water Saturation [fraction]	Oil Formation Volume Factor [rb/stb]	Permeability [mDarcies]
Arkle	1855	7.51	800	0.27	0.55	0.2	1.14	800

Fluid Properties

	Reservoir Depth [ft tvdss]	Initial Pressure [psi]	Temperature [deg F]	API Gravity	Solution GOR [scf/stb]	Bubblepoint Pressure [psi]
Arkle	6900	3200	140	24	220	3100

13.1.1 Oil Production Profile

The following recipe was followed to calculate the primary phase oil production profile.

1. Calculate likely individual well production rates.
2. From analogues reservoir performance, obtain relationship of plateau offtake rate Vs field size and cumulative production offtake prior to field decline.
3. Backsolve decline rate for required field reserve level, and compare calculated decline rate to analogue field experience. *If the decline rate is greater or less than the expected range, iterate steps 2 and 3, together with a critical review of likely field reserve level or recovery factor*.
4. Once complete, proceed to calculate the Gas Production Profile

Individual Well Production Rates

Using the reservoir and fluid properties information provided for Arkle

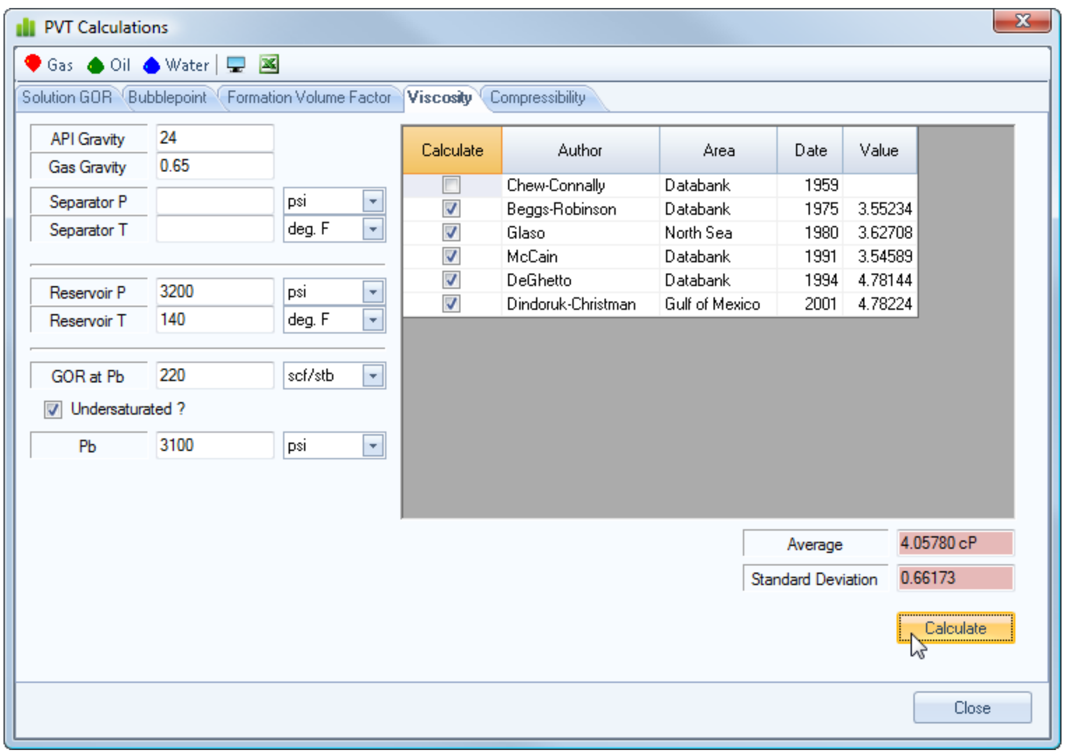
Volumetric and Reservoir Properties

	Reservoir Area [acres]	Reservoir Area [km^2]	Gross Thickness [feet]	Porosity [fraction]	Net-to-Gross ratio [fraction]	Water Saturation [fraction]	Oil Formation Volume Factor [rb/stb]	Permeability [mDarcies]
Arkle	1855	7.51	800	0.27	0.55	0.2	1.14	800

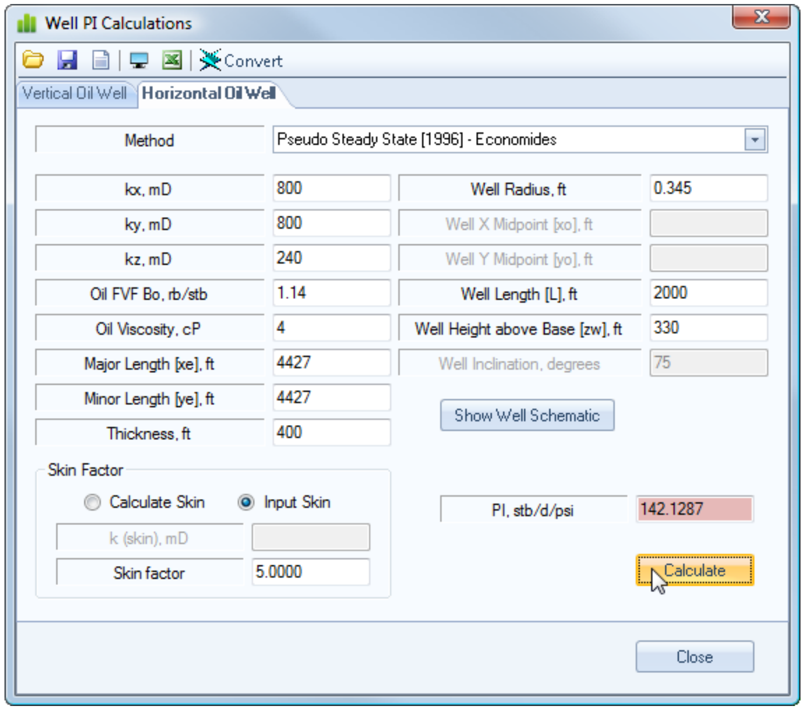
Fluid Properties

	Reservoir Depth [ft tvdss]	Initial Pressure [psi]	Temperature [deg F]	API Gravity	Solution GOR [scf/stb]	Bubblepoint Pressure [psi]
Arkle	6900	3200	140	24	220	3100

The following can be estimated for oil viscosity.



From the above the likely range for oil viscosity from low-mid-high values are 3.5 - 4.0 - 4.8 cP. These values can subsequently be used in the estimation of well PI, as shown below, assuming a horizontal wellpath, given the likely low drawdown constraints, and to improve well productivity and reduce well spacing.



The likely range of well PI is 120 - 142 -160 bopd / psi, and given a prudent 80 psi drawdown, results in an individual well target rate of 11 mstb/d, +/- 2 mstb/d.

Buildup of Production Rate to Plateau

Given a water depth of 1500 ft, and the reservoir depth of almost 7000 ft with a reservoir section of 2000 ft. It was assumed that 6 development producers and 3 injectors wells would be predrilled, prior to the production facility (most likely a FPSO) installation. These would then be tied back and first oil achieved from 6 production wells, resulting in the first years production figure of 60 mstb/d.

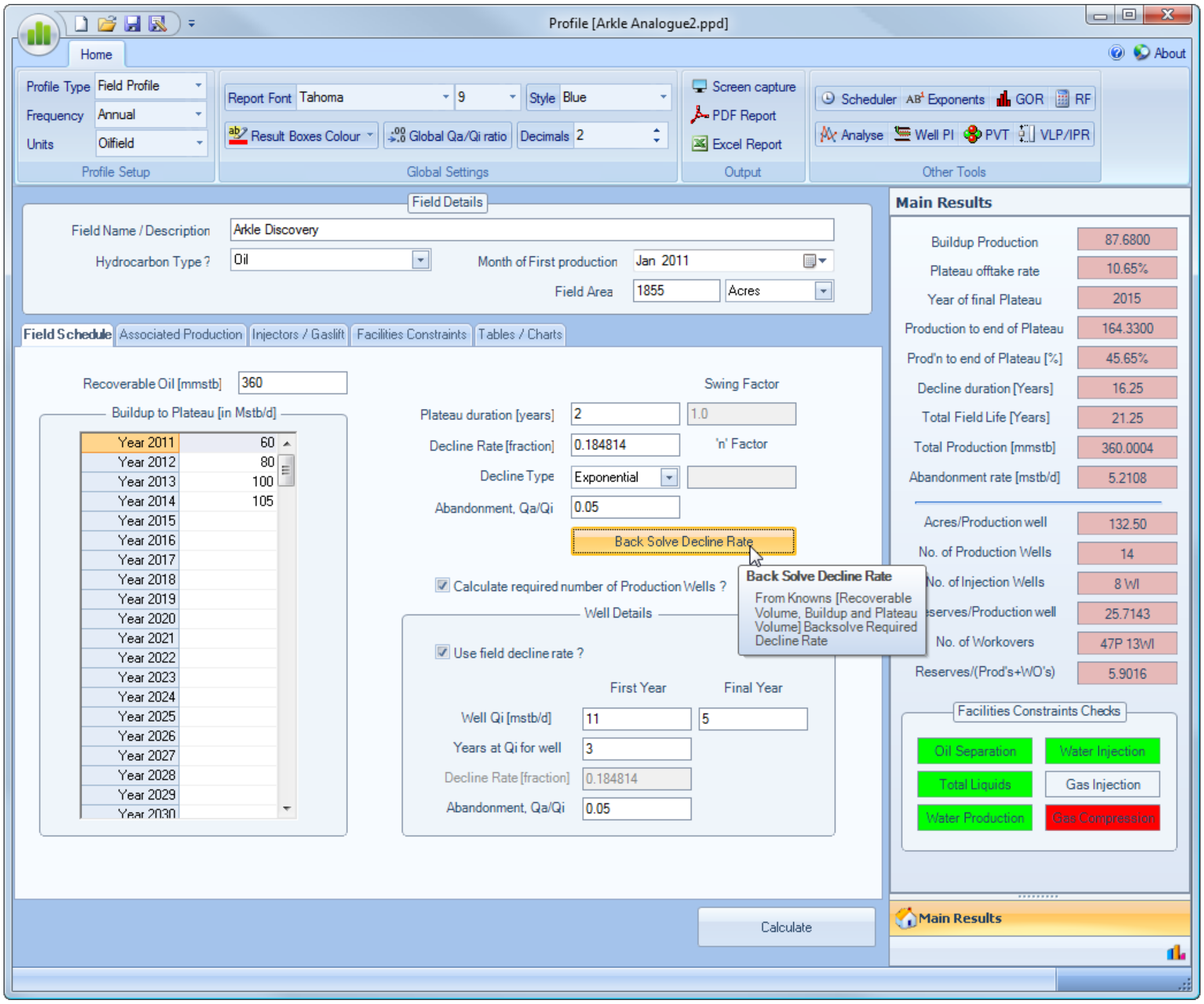
Due to likely adverse weather sea conditions, it was assumed that in subsequent years two production wells and one injection well per year would be drilled and tied back.

Plateau Offtake Rate and Onset of field Decline

From analogue fields nearby with similar geological settings and water depth, the following was calculated for plateau offtake rates :

Plateau Production Offtake Rate = 10 - 10.5 - 11%
Cumulative Offtake Rate = 40 - 45 - 50%

Given the above set of assumptions the following was put together as an initial pass at a field oil production profile.

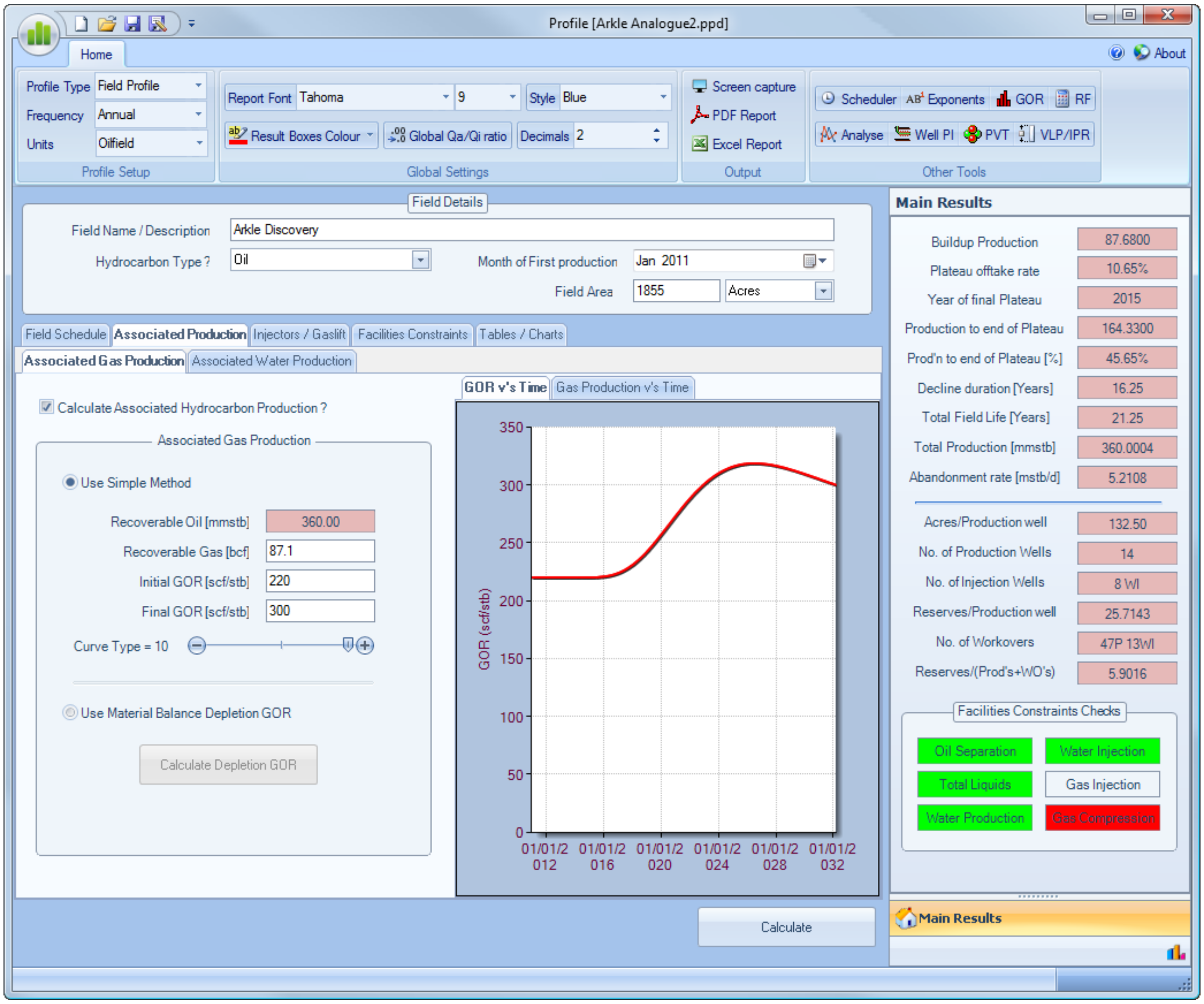


The offtake rate was iterated to 105 mstb/d in year 2014 to give a similar mid case offtake rate of 10.6 %, and the plateau duration was fixed to 2 years to give a "Production to Plateau end" of 45.6%. See the above Main Results Panel. The decline rate was then backsolved to 0.1848 per annum, which compared favourably to the nearby analogue fields.

13.1.2 Gas Production Profile

The field value for undersaturated gas oil ratio is 220 scf/stb, with the original reservoir pressure of 3200 psi compared with the bubble point pressure of 3100 psi.

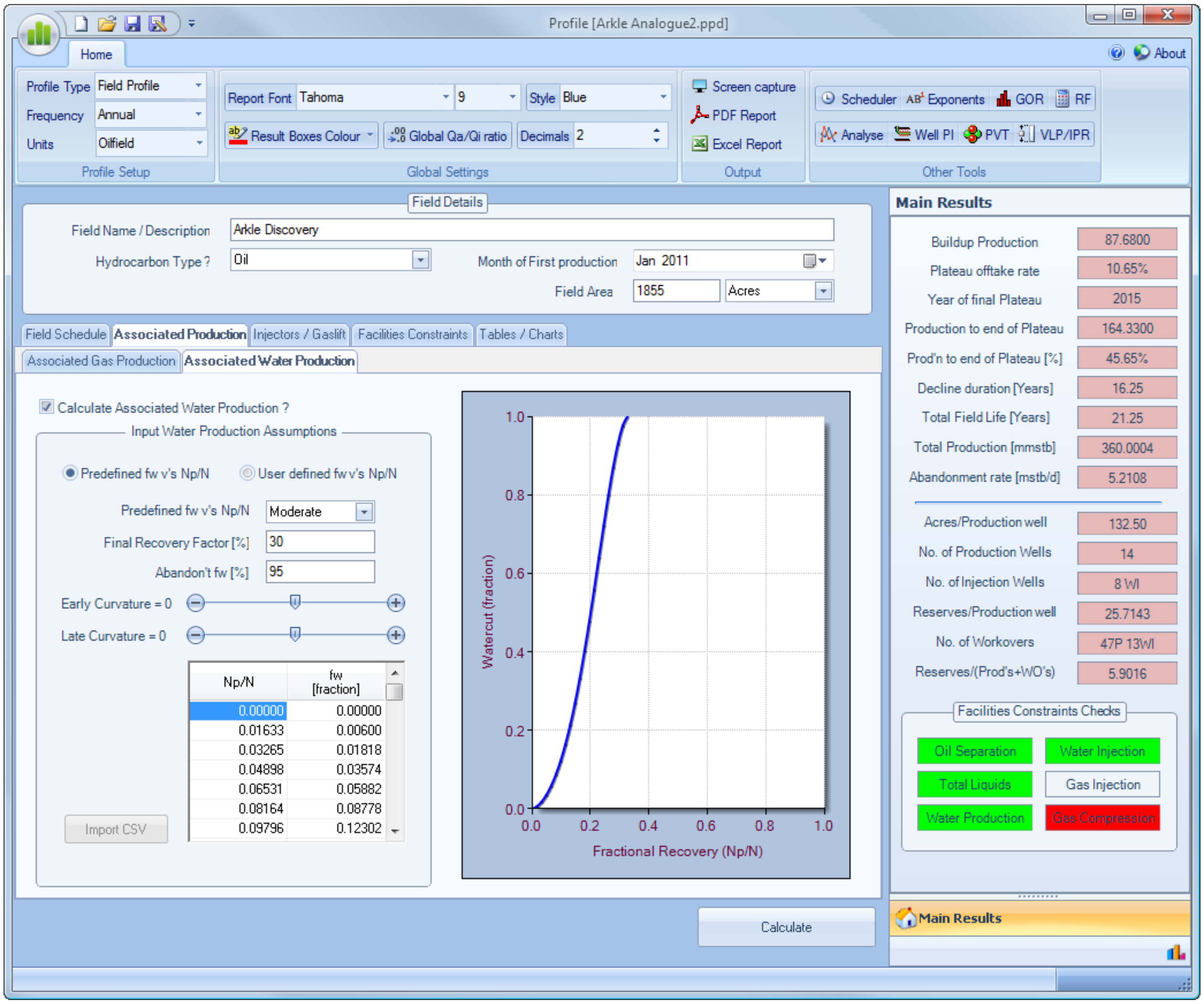
The development assumption is for full voidage replacement, provided by water injection, akin to the practice and experience of nearby analogues. However, it is assumed that some local gas breakout would occur near to the end of production plateau. Therefore is was assumed that the GOR would gradually climb to 300 scf/stb, with a resultant field recoverable gas recovery of 87.1 bcf (= 110% of 360 mmstb x 220 scf/stb). The resultant input screen is shown below.



13.1.3 Water Production Profile

From the input assumptions, it can be seen that the assumed ultimate recovery factor is 30%. This ultimate recovery corresponds to an abandonment watercut of approximately 95%, and it is also assumed that the watercut development would be "Moderate".

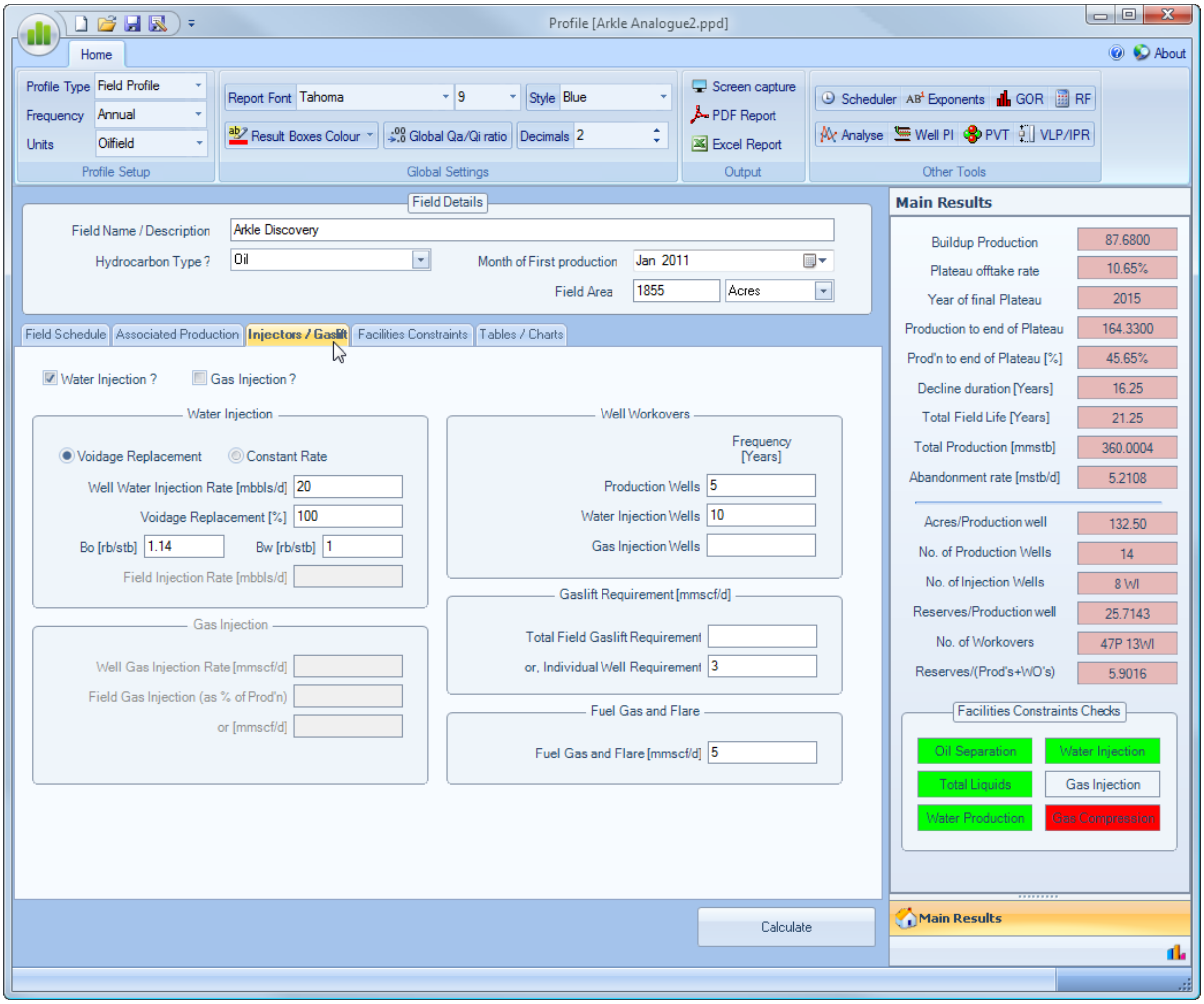
These assumptions are input as shown below to calculate the water production profile.



13.1.4 Water Injection Profile

As already mentioned, the development assumption is for full voidage replacement, provided by water injection, akin to the practice and experience of nearby analogues.

It is also assumed that the injectors will perform better than the producers, since the water viscosity is lower than the oil viscosity and the likelihood that the injectors will be fractured (either hydraulically or thermally) hence improving injectivity performance. It was assumed that individual injectors would be capable to inject a constant rate of 20 mstb/d.

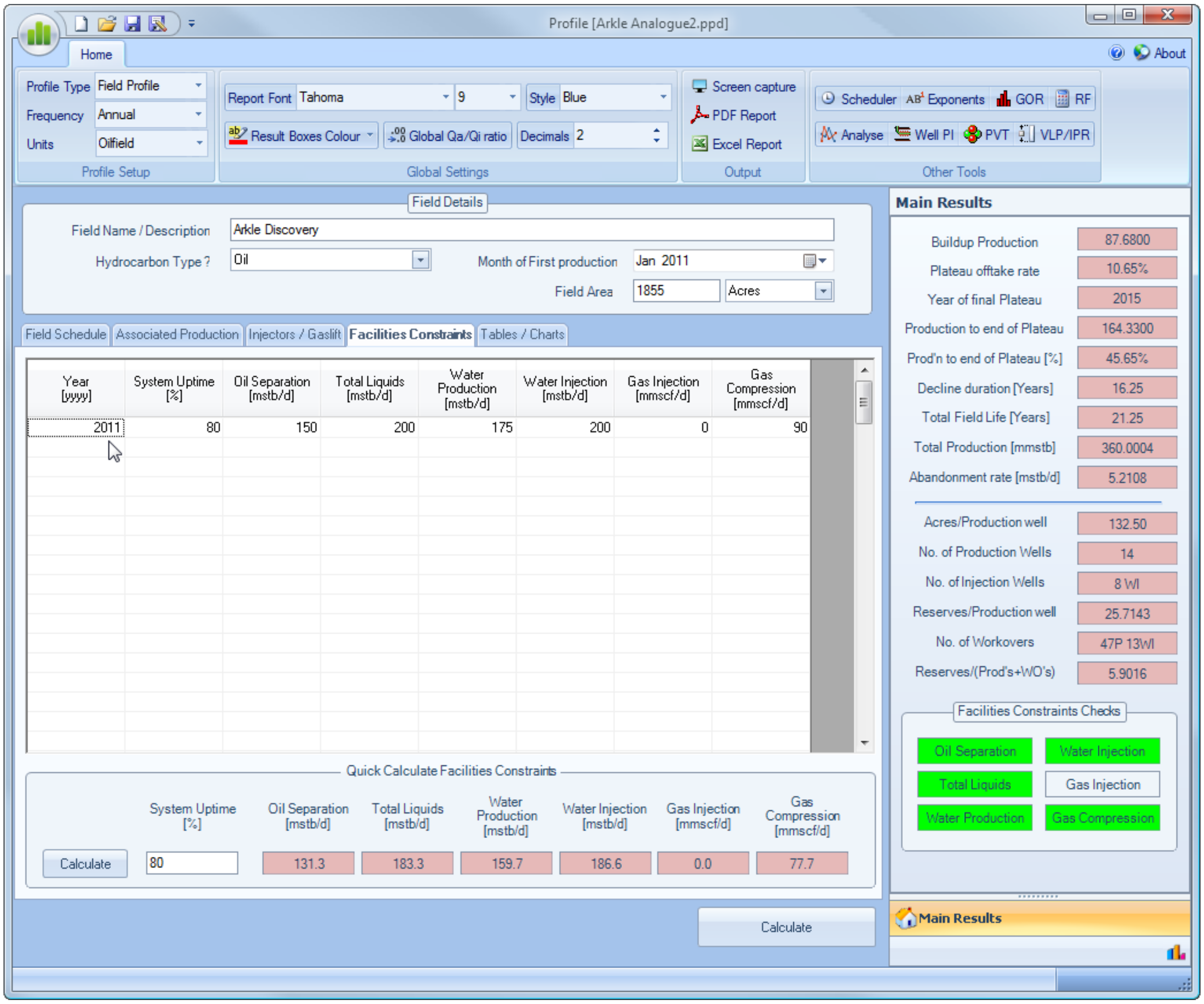


Workovers were also tentatively modeled to occur every 5 years per producer and every 10 years per injector, to give an approximate idea of when to schedule workover batches.

Also, it is assumed that 3 mmscf/d per producer will be available for gaslift to enable lifting these wells at mature watercut levels. This assumption, together with the assumption of 5 mmscf/d for fuel and flare gas, will help size the total gas compression requirement.

13.1.5 Facilities Sizing

Now that we are happy with the oil, gas and water production profiles and water injection assumptions, we input the 80% uptime figure in the "Quick Calculate Facilities Constraints" section, as shown below, then press the *Calculate* button. The routine then searches through each of the production and injection streams, finds each of the maximum values, then multiplies the maximums by the (1 / Uptime).

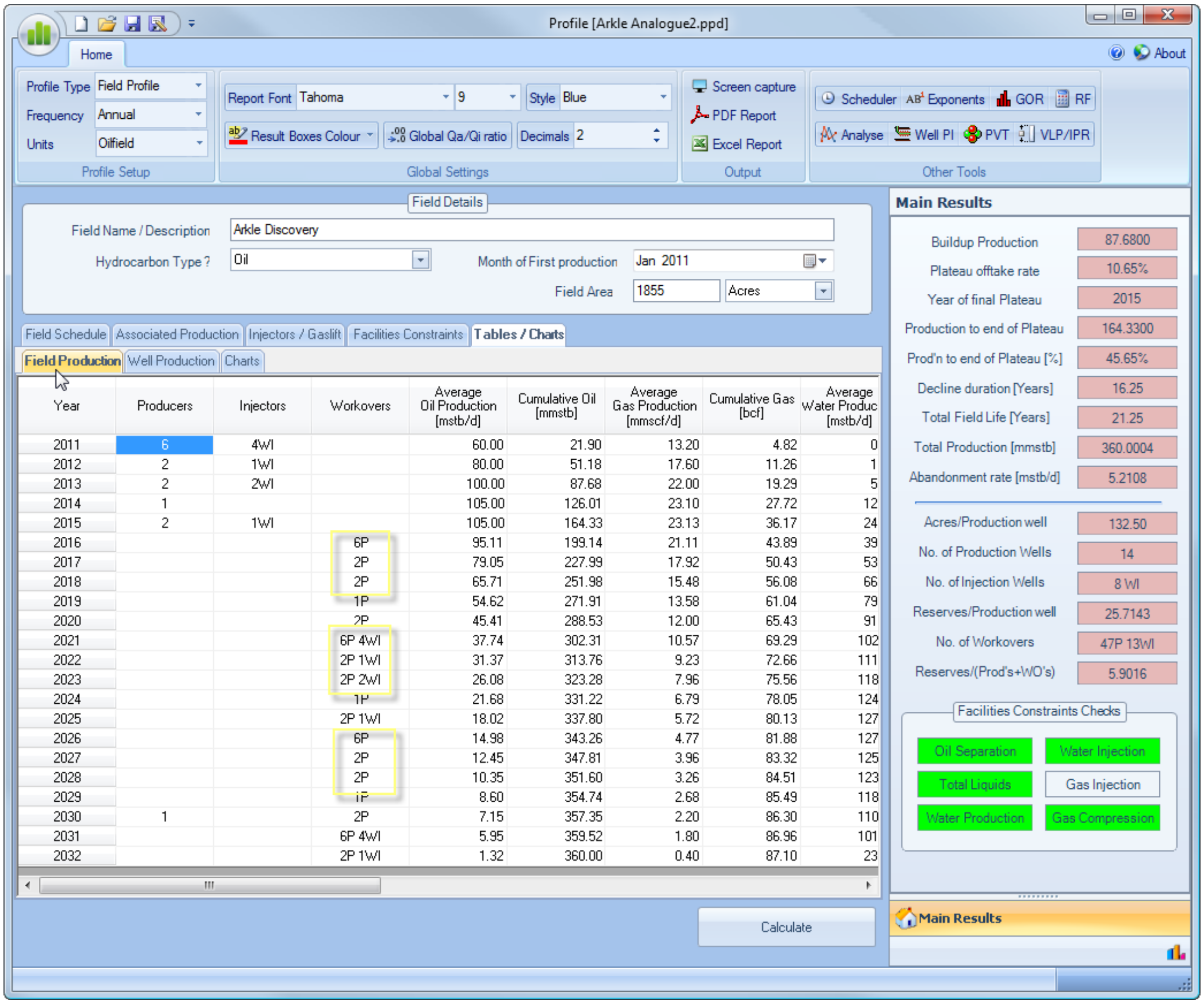


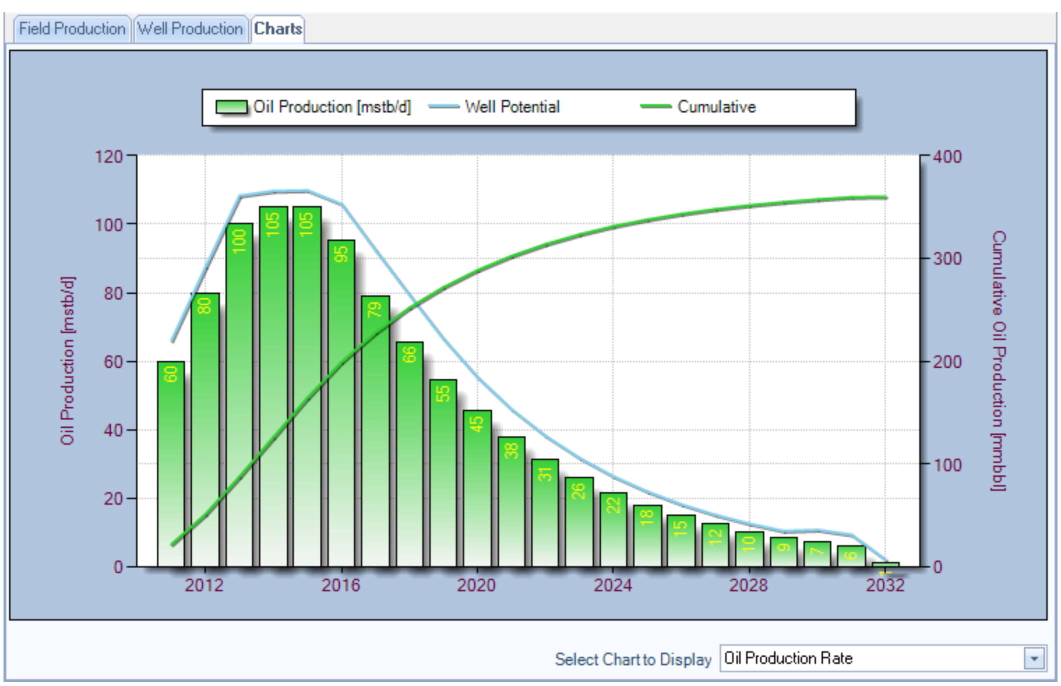
The user can then input approximate facilities constraints into the table above, then press the main application *Calculate* button to allow the application to run through the *Facilities Constraints Checks* traffic light system, as also shown above.

13.1.6 Results

Now that we are happy with all the input and calculations with regards to the production and injection profiles, we can inspect the output tables and charts.

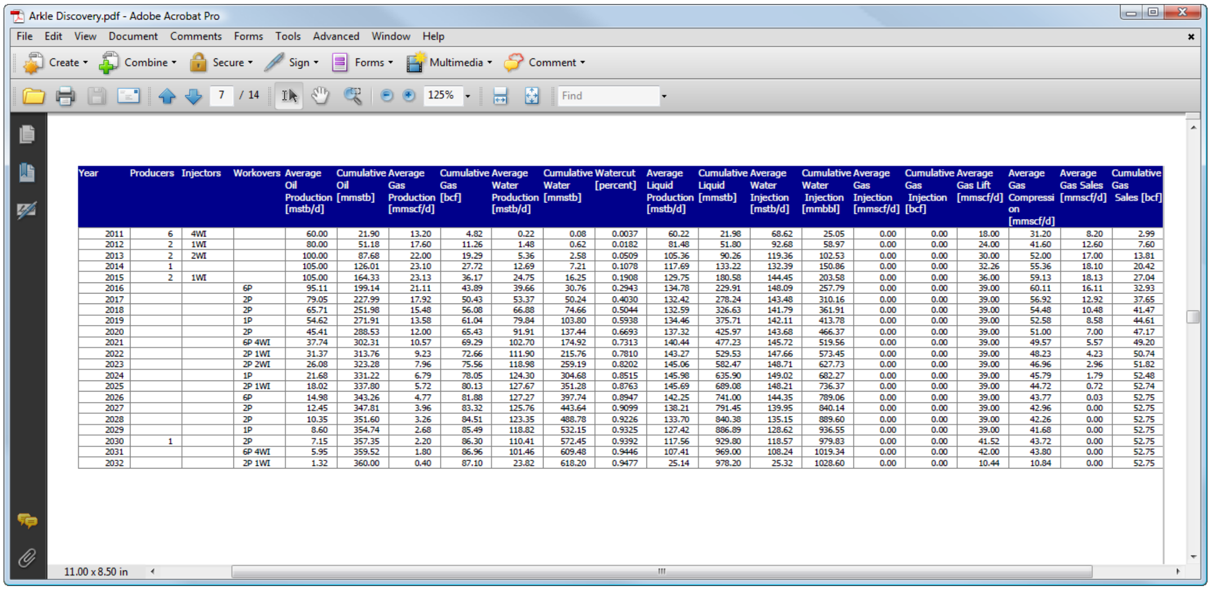
For example, the output *Field Production* table below highlights an interesting observation with regards to workover scheduling. There appears to be three logical perdiods in which to conduct batch workover programs, first in 2016 or 2017, then in 2021 and finally in 2026. The workovers proposed for 2028 onwards can probably be ignored, since it is unlikely that there will be any workover operating cost work done when the field is so close to final abandonment.


Profile [Arkle Analogue2.ppd]
Home
About
Profile Type Field Profile
Frequency Annual
Units Oilfield
Profile Setup
Report Font Tahoma
Style Blue
Result Boxes Colour
Global Qa/Qi ratio
Decimals 2
Global Settings
Screen capture
PDF Report
Excel Report
Output
Scheduler
Exponents
GOR
RF
Analyse
Well PI
PVT
VLP/IPR
Other Tools
Field Details
Field Name / Description Arkle Discovery
Hydrocarbon Type ? Oil
Month of First production Jan 2011
Field Area 1855 Acres
Field Schedule
Associated Production
Injectors / Gaslift
Facilities Constraints
Tables / Charts
Field Production
Well Production
Charts
Calculate
Main Results
Buildup Production 87.6800
Plateau offtake rate 10.65%
Year of final Plateau 2015
Production to end of Plateau 164.3300
Prod'n to end of Plateau [%] 45.65%
Decline duration [Years] 16.25
Total Field Life [Years] 21.25
Total Production [mmstb] 360.0004
Abandonment rate [mstb/d] 5.2108
Acres/Production well 132.50
No. of Production Wells 14
No. of Injection Wells 8 WI
Reserves/Production well 25.7143
No. of Workovers 47P 13WI
Reserves/(Prod's+WO's) 5.9016
Facilities Constraints Checks
Oil Separation
Water Injection
Total Liquids
Gas Injection
Water Production
Gas Compression
Main Results


Field Production
Well Production
Charts
Oil Production [mstb/d]
Well Potential
Cumulative
Oil Production [mstb/d]
Cumulative Oil Production [mmbbl]
2012
2016
2020
2024
2028
2032
Select Chart to Display Oil Production Rate

With the following calculations exported as an Adobe 'pdf' file or a Microsoft Excel file, and available to email to the Facilities Design Engineer, and Economists for future cashflow forecasting, the job of generating the field life production and injection profiles is now complete.

Time taken to complete = between 5 minutes and 1 hour, depending on how familiar the Engineer is with representative analogue data.



Year	Producers	Injectors	Workovers	Average Oil Production [mstb/d]	Cumulative Oil [mmstb]	Average Gas Production [mmscf/d]	Cumulative Gas [bcf]	Average Water Production [mstb/d]	Cumulative Water [mmstb]	Watercut [percent]	Average Liquid Production [mstb/d]	Cumulative Liquid [mmstb]	Average Water Injection [mstb/d]	Cumulative Water Injection [mmbbl]	Average Gas Injection [mmscf/d]	Cumulative Gas Injection [bcf]	Average Gas Lift [mmscf/d]	Average Gas Compression [mmscf/d]	Average Gas Sales [mmscf/d]	Cumulative Gas Sales [bcf]
2011	6	4WI		60.00	21.90	13.20	4.82	0.22	0.08	0.0037	60.22	21.98	68.62	25.05	0.00	0.00	18.00	31.20	8.20	2.99
2012	2	1WI		80.00	51.18	17.60	11.26	1.48	0.62	0.0182	81.48	51.80	92.68	58.97	0.00	0.00	24.00	41.60	12.60	7.60
2013	2	2WI		100.00	87.68	22.00	19.29	5.36	2.58	0.0509	105.36	90.26	119.36	102.53	0.00	0.00	30.00	52.00	17.00	13.81
2014	1			105.00	126.01	23.10	27.72	12.69	7.21	0.1078	117.69	133.22	132.39	150.86	0.00	0.00	32.26	55.36	18.10	20.42
2015	2	1WI		105.00	164.33	23.13	36.17	24.75	16.25	0.1908	129.75	180.58	144.45	203.58	0.00	0.00	36.00	59.13	18.13	27.04
2016			6P	95.11	199.14	21.11	43.89	39.66	30.76	0.2943	134.78	229.91	148.09	257.79	0.00	0.00	39.00	60.11	16.11	32.93
2017			2P	79.05	227.99	17.92	50.43	53.37	50.24	0.4030	132.42	278.24	143.48	310.16	0.00	0.00	39.00	56.92	12.92	37.65
2018			2P	65.71	251.98	15.48	56.08	66.88	74.66	0.5044	132.59	326.63	141.79	361.91	0.00	0.00	39.00	54.48	10.48	41.47
2019			1P	54.62	271.91	13.58	61.04	79.84	103.80	0.5938	134.46	375.71	142.11	413.78	0.00	0.00	39.00	52.58	8.58	44.61
2020			2P	45.41	288.53	12.00	65.43	91.91	137.44	0.6693	137.32	425.97	143.68	466.37	0.00	0.00	39.00	51.00	7.00	47.17
2021			6P 4WI	37.74	302.31	10.57	69.29	102.70	174.92	0.7313	140.44	477.23	145.72	519.56	0.00	0.00	39.00	49.57	5.57	49.20
2022			2P 1WI	31.37	313.76	9.23	72.66	111.90	215.76	0.7810	143.27	529.53	147.66	573.45	0.00	0.00	39.00	48.23	4.23	50.74
2023			2P 2WI	26.08	323.28	7.96	75.56	118.98	259.19	0.8202	145.06	582.47	148.71	627.73	0.00	0.00	39.00	46.96	2.96	51.82
2024			1P	21.68	331.22	6.79	78.05	124.30	304.68	0.8515	145.98	635.90	149.02	682.27	0.00	0.00	39.00	45.79	1.79	52.48
2025			2P 1WI	18.02	337.80	5.72	80.13	127.67	351.28	0.8763	145.69	689.08	148.21	736.37	0.00	0.00	39.00	44.72	0.72	52.74
2026			6P	14.98	343.26	4.77	81.88	127.27	397.74	0.8947	142.25	741.00	144.35	789.06	0.00	0.00	39.00	43.77	0.03	52.75
2027			2P	12.45	347.81	3.96	83.32	125.76	443.64	0.9099	138.21	791.45	139.95	840.14	0.00	0.00	39.00	42.96	0.00	52.75
2028			2P	10.35	351.60	3.26	84.51	123.35	488.78	0.9226	133.70	840.38	135.15	889.60	0.00	0.00	39.00	42.26	0.00	52.75
2029			1P	8.60	354.74	2.68	85.49	118.82	532.15	0.9325	127.42	886.89	128.62	936.55	0.00	0.00	39.00	41.68	0.00	52.75
2030	1		2P	7.15	357.35	2.20	86.30	110.41	572.45	0.9392	117.56	929.80	118.57	979.83	0.00	0.00	41.52	43.72	0.00	52.75
2031			6P 4WI	5.95	359.52	1.80	86.96	101.46	609.48	0.9446	107.41	969.00	108.24	1019.34	0.00	0.00	42.00	43.80	0.00	52.75
2032			2P 1WI	1.32	360.00	0.40	87.10	23.82	618.20	0.9477	25.14	978.20	25.32	1028.60	0.00	0.00	10.44	10.84	0.00	52.75

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