EORgui Help

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Graphical User Interface for the United States of America, Department of Energy, Publicly Available EOR Software.

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by Petroleum Solutions Ltd

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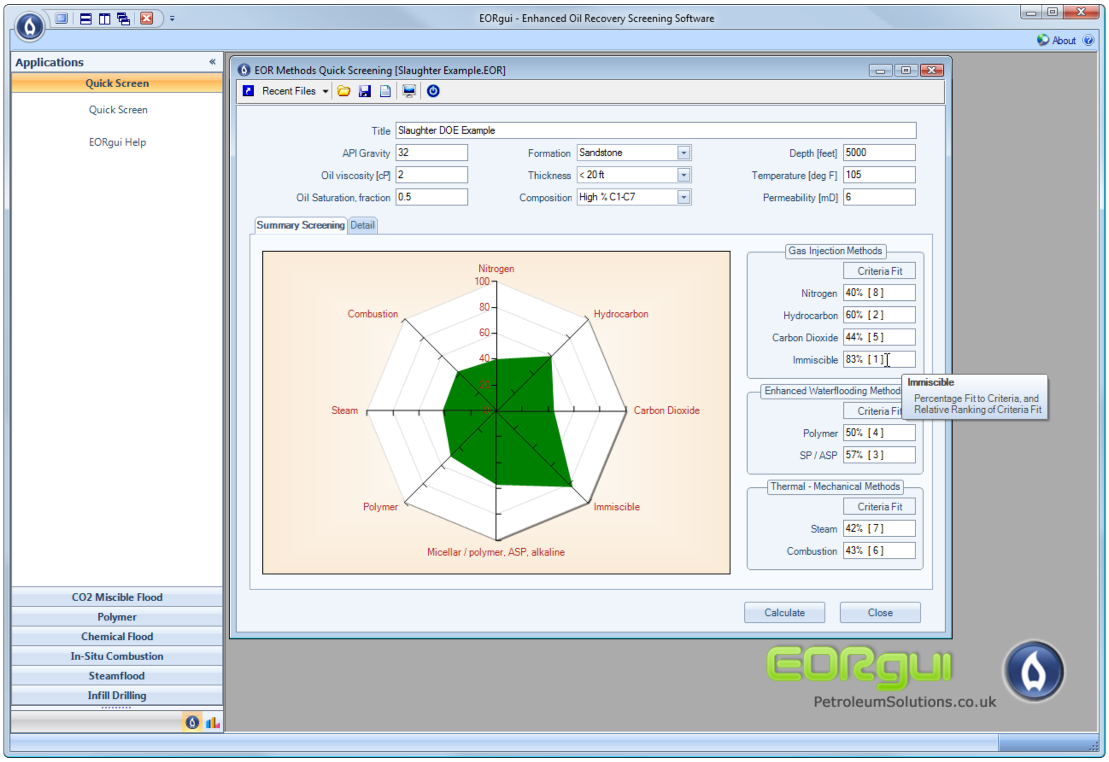
Part I

1 Welcome to EORgui

1.1 Introduction



EORgui is a Graphical User Interface for the United States of America, Department of Energy, National Energy Technology Laboratory, Publicly Available EOR Software.

Through the use of this application, the user can quickly screen oil fields and quantify incremental production for potentially applicable EOR techniques.

This graphical user interface (GUI) application :

- Quickly screen and rank appropriate EOR methods for a given set of summary reservoir and fluid properties.
- Prepares the input files required for the technical analysis portions of the publicly available fortran applications. Namely, the GUI does not prepare the input required to calculate the economic analysis that is also available within these publicly available software.
- The GUI runs the fortran applications and imports the results back into the application.
- The results are input into convenient data tables for export into other applications (eg. Microsoft Excel), and also plotted in high output quality charts for use with other applications (eg. Microsoft Powerpoint).

License.dat File

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

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

The Profile 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 Waterdrive.

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 [Dotnetfx2.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

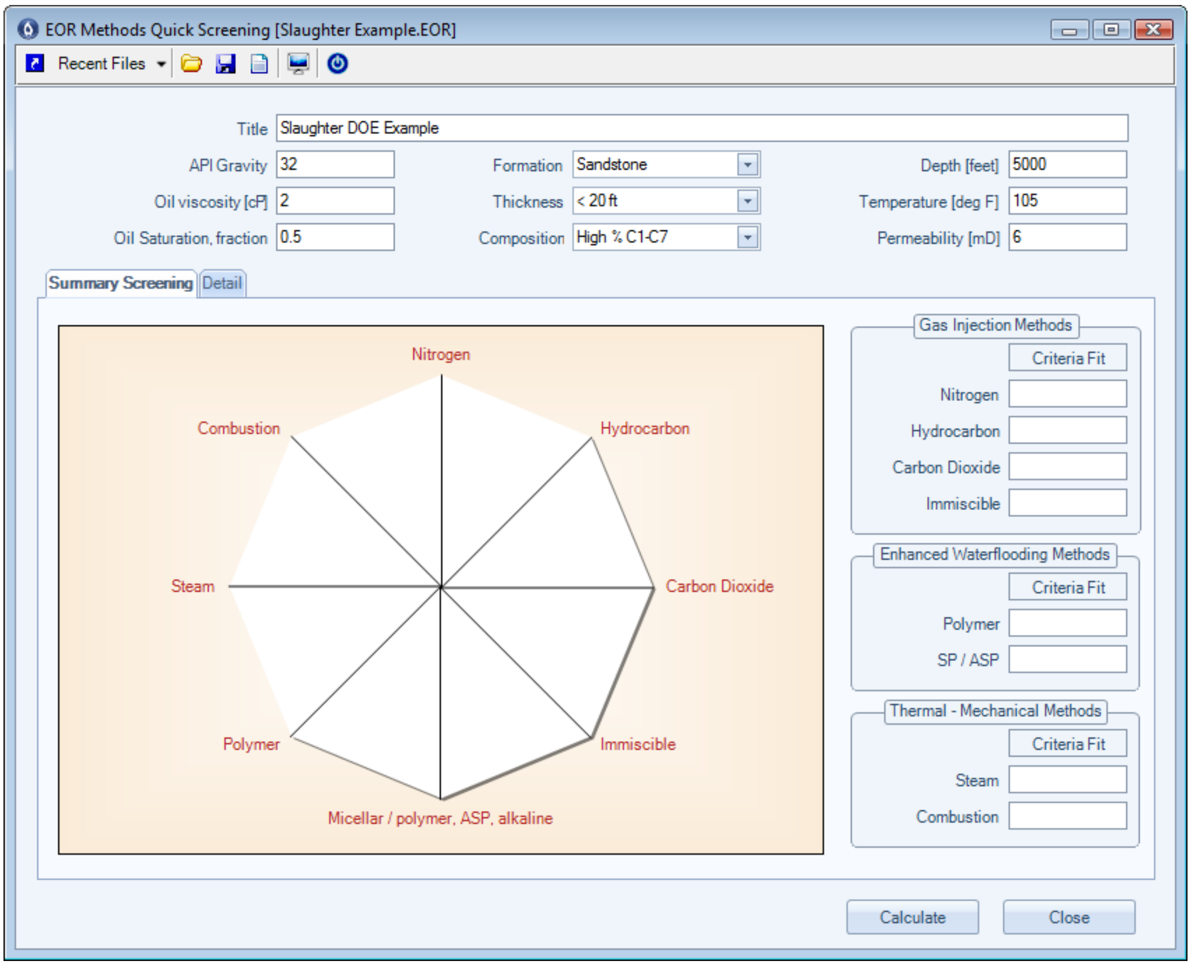
CPU Recommended	RAM Recommended
Pentium 90 MHz or faster	96 MB or higher

Part II

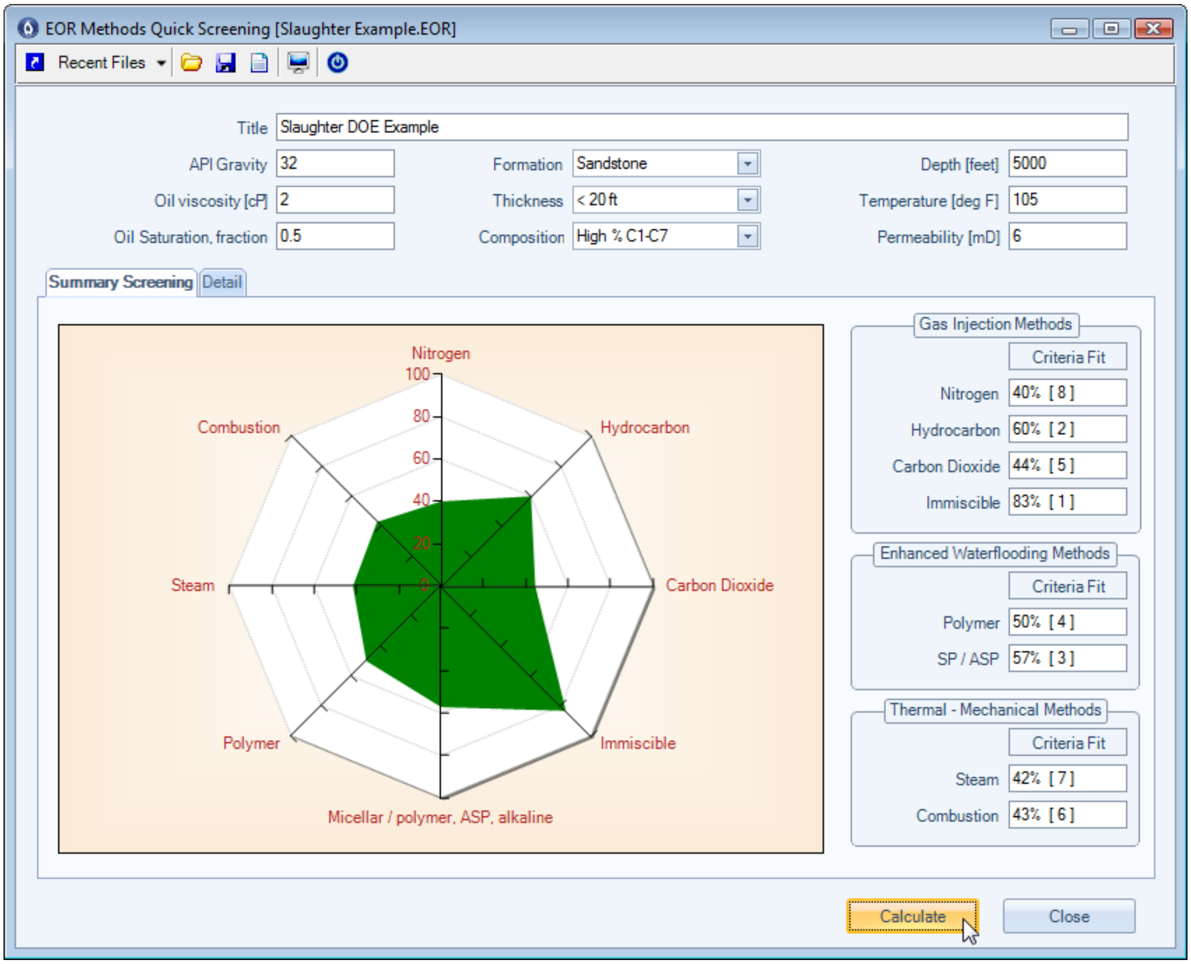
2 EORgui Sections

2.1 Quick Screening

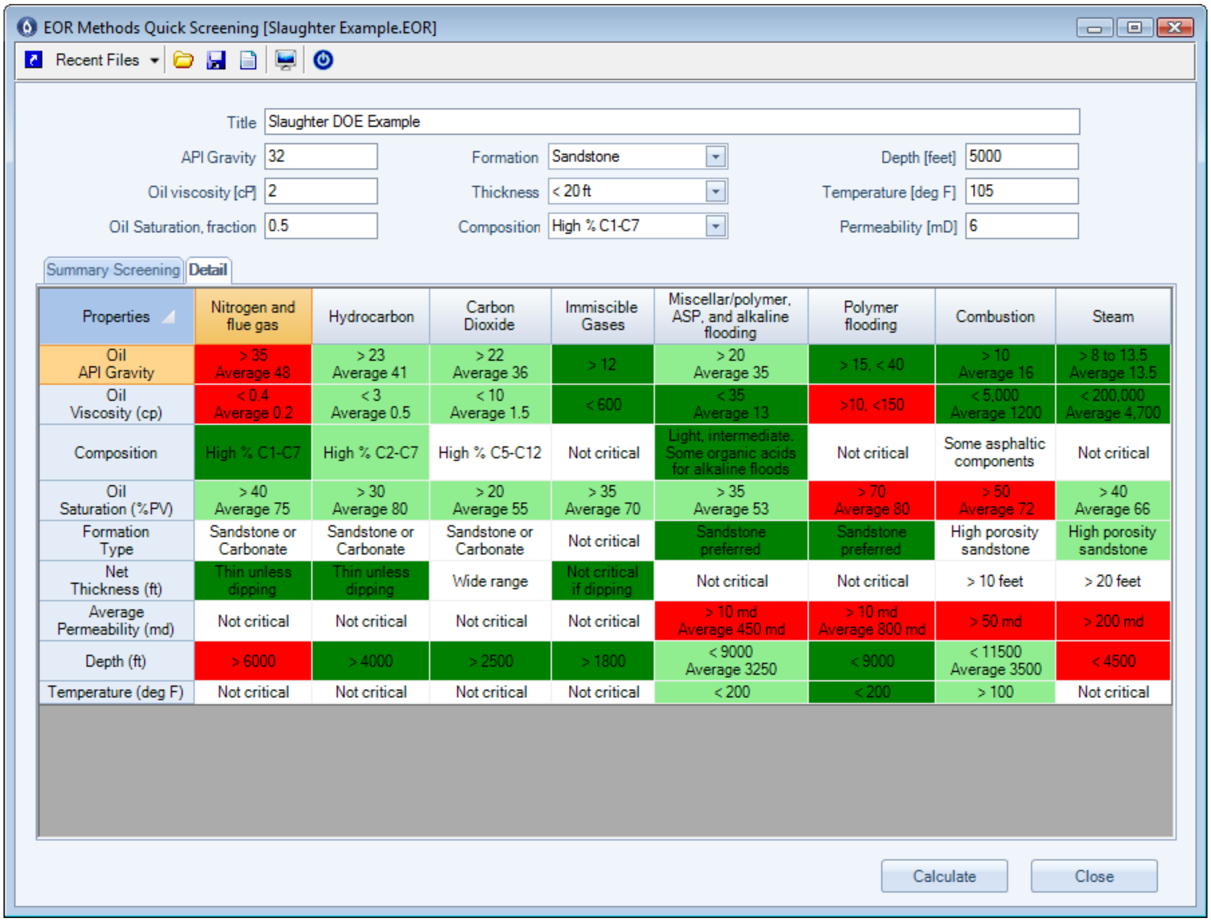
This routine is based on the 1996 Society of Petroleum Engineers Paper entitled "*EOR Screening Criteria Revisited*" by Taber, Martin, and Seright. Contained within this paper are concise screening guidelines for various EOR techniques, all of which are listed in the table provided in the *Detail* tab, as shown in the third figure below.



Once the user has input all the necessary data, then press the *Calculate* button to calculate the relative Criteria fit to the input data.



The results are shown in both summary chart and a colour coded results table.



Properties	Nitrogen and flue gas	Hydrocarbon	Carbon Dioxide	Immiscible Gases	Miscellar/polymer, ASP, and alkaline flooding	Polymer flooding	Combustion	Steam
Oil API Gravity	> 35 Average 48	> 23 Average 41	> 22 Average 36	> 12	> 20 Average 35	> 15, < 40	> 10 Average 16	> 8 to 13.5 Average 13.5
Oil Viscosity (cp)	< 0.4 Average 0.2	< 3 Average 0.5	< 10 Average 1.5	< 600	< 35 Average 13	>10, <150	< 5,000 Average 1200	< 200,000 Average 4,700
Composition	High % C1-C7	High % C2-C7	High % C5-C12	Not critical	Light, intermediate. Some organic acids for alkaline floods	Not critical	Some asphaltic components	Not critical
Oil Saturation (%PV)	> 40 Average 75	> 30 Average 80	> 20 Average 55	> 35 Average 70	> 35 Average 53	> 70 Average 80	> 50 Average 72	> 40 Average 66
Formation Type	Sandstone or Carbonate	Sandstone or Carbonate	Sandstone or Carbonate	Not critical	Sandstone preferred	Sandstone preferred	High porosity sandstone	High porosity sandstone
Net Thickness (ft)	Thin unless dipping	Thin unless dipping	Wide range	Not critical if dipping	Not critical	Not critical	> 10 feet	> 20 feet
Average Permeability (md)	Not critical	Not critical	Not critical	Not critical	> 10 md Average 450 md	> 10 md Average 800 md	> 50 md	> 200 md
Depth (ft)	> 6000	> 4000	> 2500	> 1800	< 9000 Average 3250	< 9000	< 11500 Average 3500	< 4500
Temperature (deg F)	Not critical	Not critical	Not critical	Not critical	< 200	< 200	> 100	Not critical

In the example provided above, the most appropriate EOR methods appear to be immiscible gas injection, followed by perhaps CO2 injection.

The colouring scheme is simply based on the degree in which the criteria is met or not. Namely, if a cell is coloured red then this criteria is not met, whereas if a cell is coloured light green then the criteria is just met, whereas if the cell is coloured dark green then the criteria is well met.

References:

Taber, J., Martin, D., Seright, R.,"*EOR Screening Criteria Revisited",* SPE 35385, 1996.

Taber, J., Martin, D., Seright, R.,"*EOR Screening Criteria Revisited - Part 2: Applications and Impact of Oil Prices",* SPE 39234, 1997.

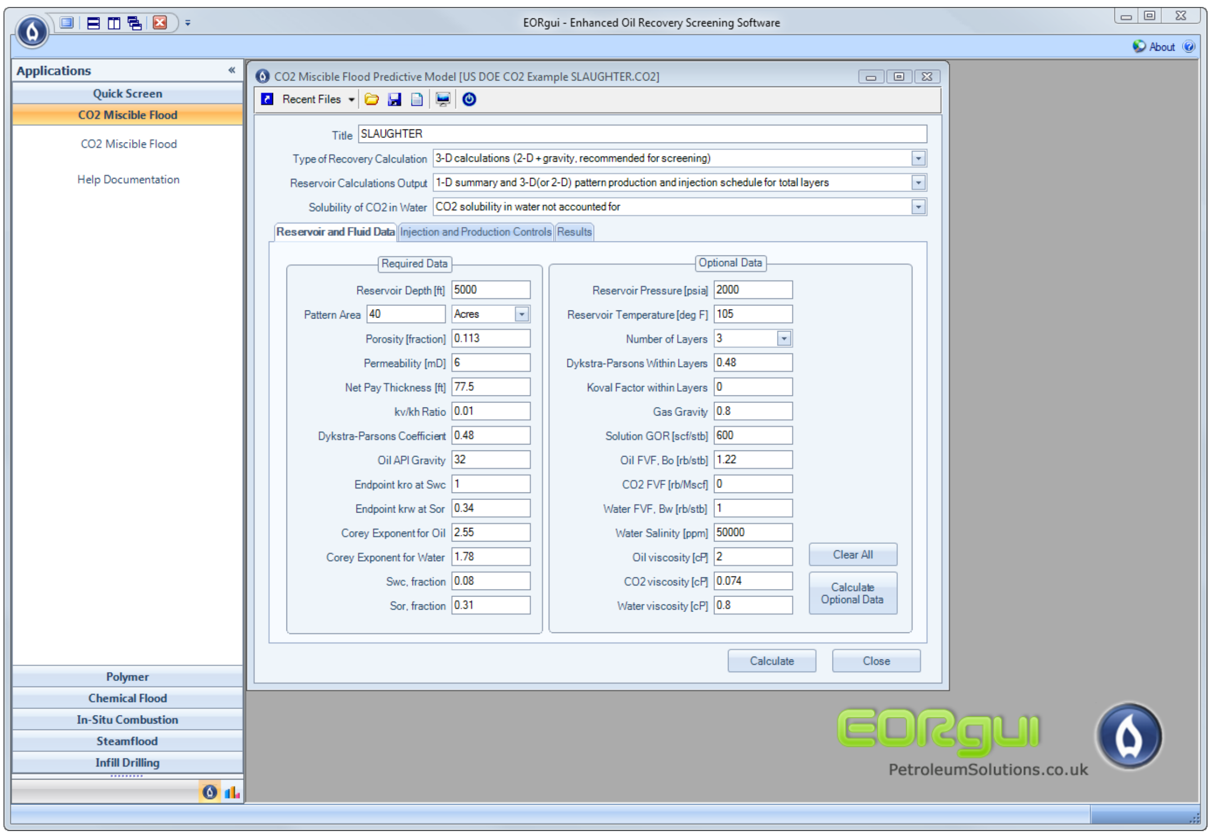
2.2 CO2 Miscible Flooding Predictive Model

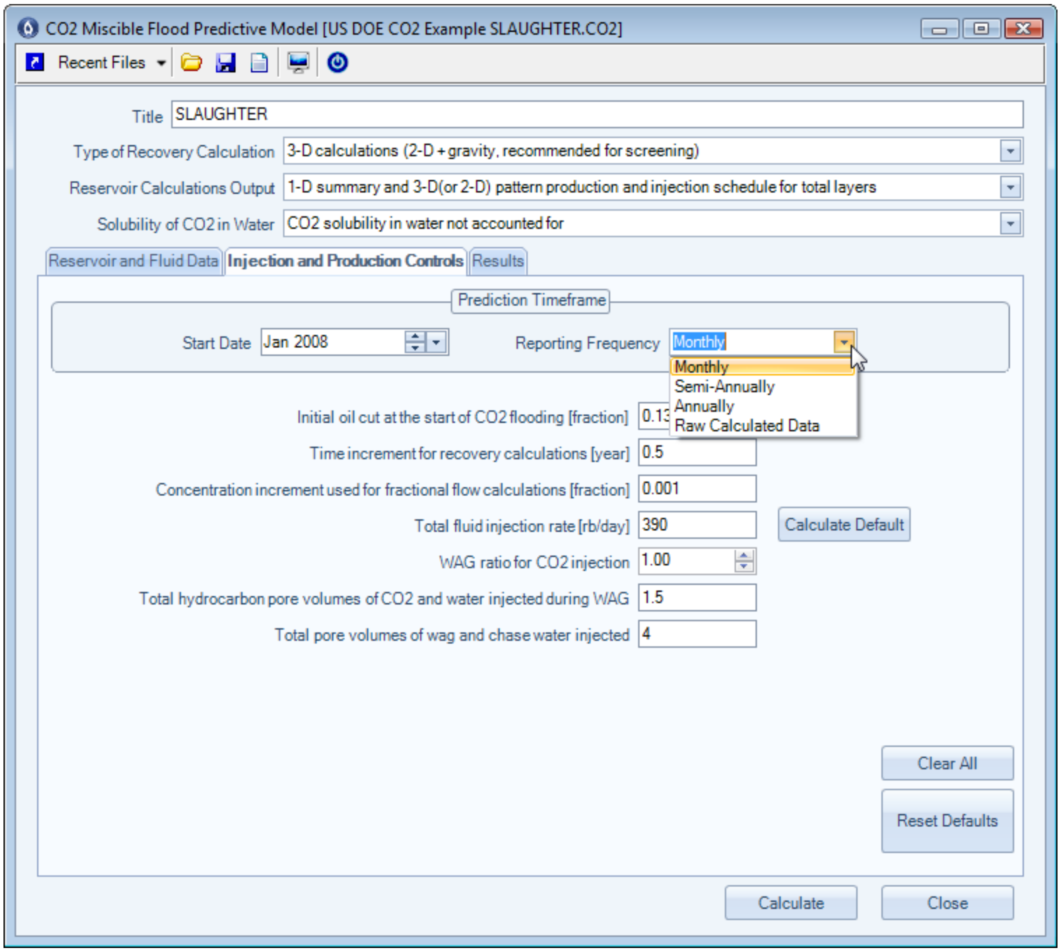
The CO2 flooding process consists of injecting large quantities of CO2 into the reservoir. Although CO2, is not first-contact miscible with the crude oil, the CO2 extracts the light-to-intermediate components from the oil, and, if the pressure is high enough, develops miscibility to displace the crude oil from the reservoir. Immiscible displacements are less effective, but they recover oil better than waterflooding.

CO2 recovers oil by swelling the crude oil, lowering the viscosity of the oil and lowering the interfacial tension between the oil and the CO2 phase in the near miscible region.

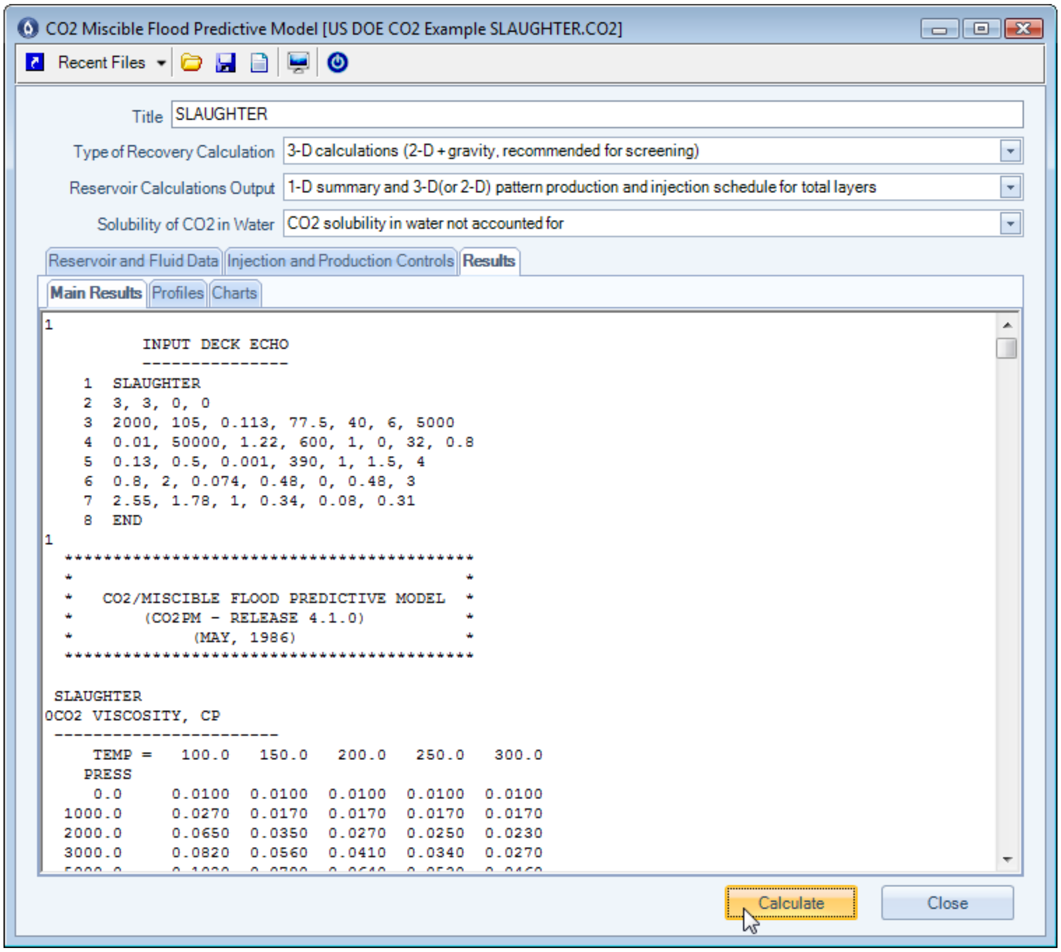
The following description is taken from the US Department of Energy CO2 Predictive Model (CO2PM) documentation.

"The CO2PM is a three-dimensional (layered, five-spot), two-phase (aqueous and oleic), three component (oil, water, and C02) model. It computes oil and C02 breakthrough and recovery from fractional theory modified for the effects of viscous fingering, areal sweep, vertical heterogeneity and gravity segregation. One-dimensional fractional flow theory is applied to first-contact miscible displacements in the presence of a second immiscible phase. The theory is based on a specialized version of the method of characteristics known as coherence or simple wave theory. The theory incorporates the Koval (1963) factor method to account for unstable miscible displacements (fingering). An extension of the Koval approach is used to model the influence of gravity segregation. Reservoir heterogeneity is accounted for by allowing up to five layers in the model, with permeabilities computed from a user-specified Dykstra-Parsons (1950) coefficient. The fractional flow theory with gravity and heterogeneity dependence is corrected for areal sweep with a generalization of Claridge's (1972) procedure to first-contact miscible floods of arbitrary WAG ratios and arbitrary initial conditions."

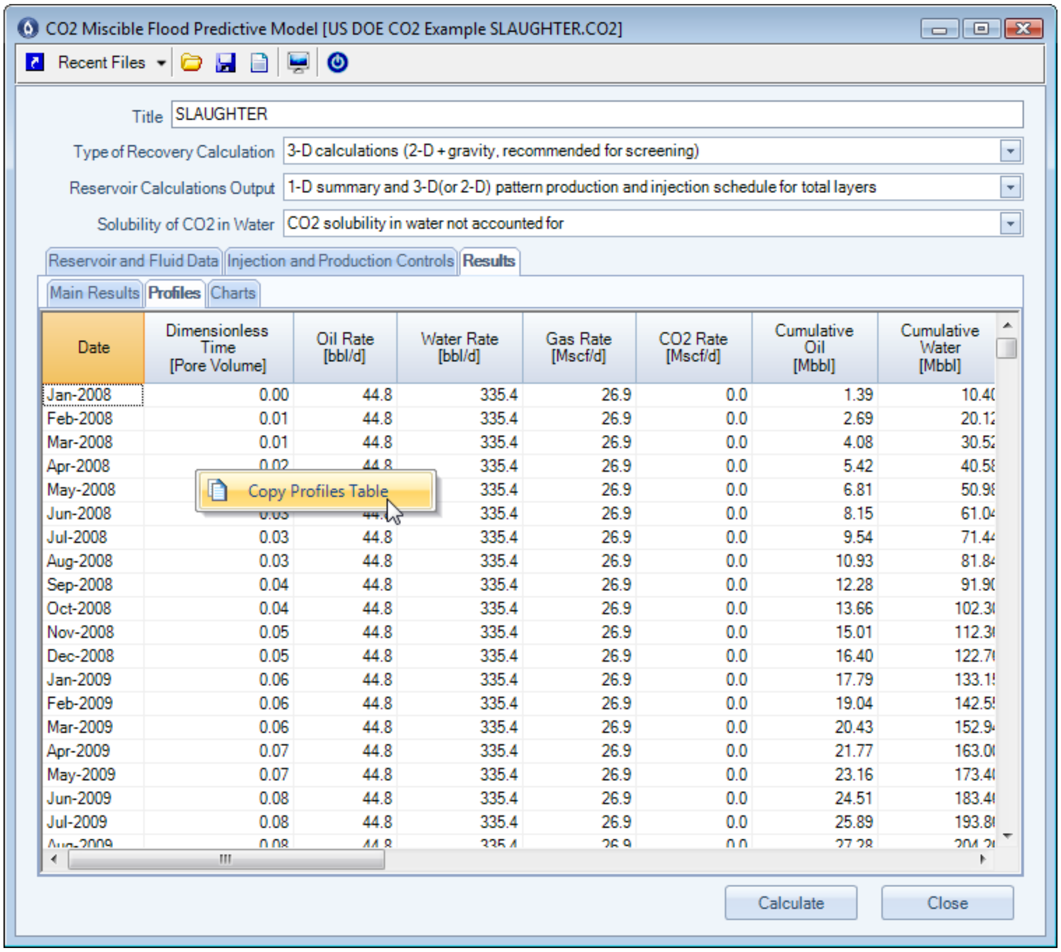




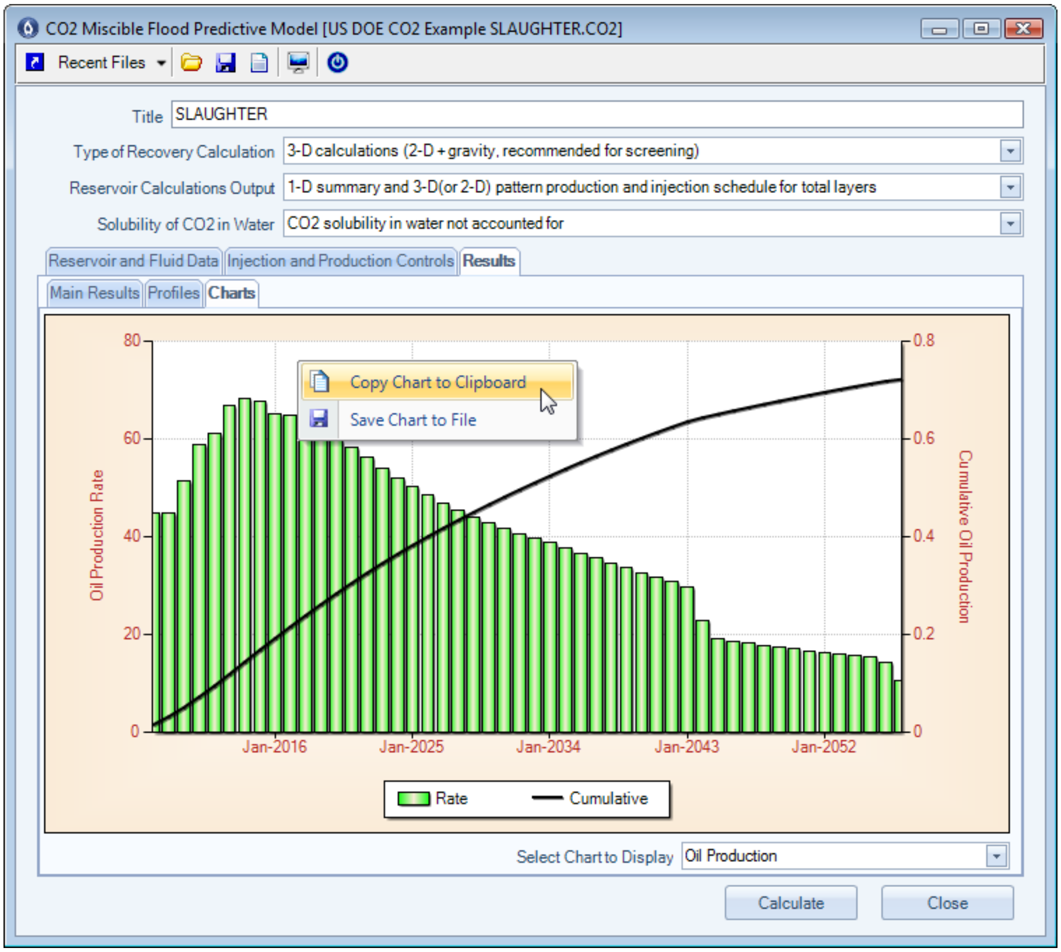
Once the user has pressed the Calculate button, the results data will be re-imported back into the application and displayed as shown in the following three screen captures below.



The user can copy the data from the data tables to the Windows clipboard for use with other applications, such as Microsoft Excel. To display the context menu shown below, simply single right-mouse-click while over the data table.



The user can also copy the active chart to the Windows clipboard for use with other applications, such as Microsoft Powerpoint.



2.3 Chemical Flood Predictive Model

All chemical flooding methods recover oil by lowering the interfacial tension between the oil and water, solubization of oil in some micellar systems and mobility enhancement.

Limitations

- An areal sweep of more than 50% on waterflood is desired.
- Relatively homogeneous formation is preferred.
- High amounts of anhydrite, gypsum, or clays are undesirable.
- Available systems provide optimum behavior over a narrow set of conditions.
- With commercially available surfactants, formation water chlorides should be <20,000 pprn and divalent ions (Ca^{++} and Mg^{++}) <500 ppm.

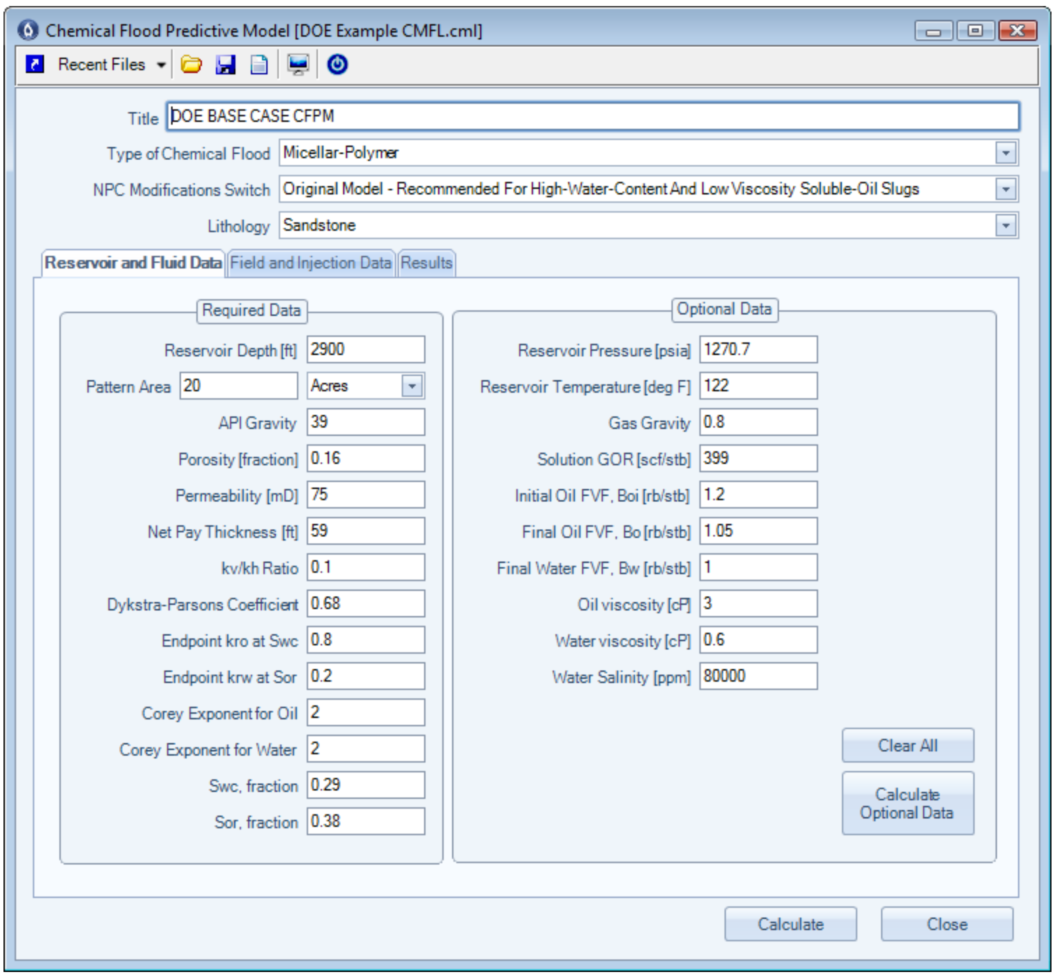
Problems

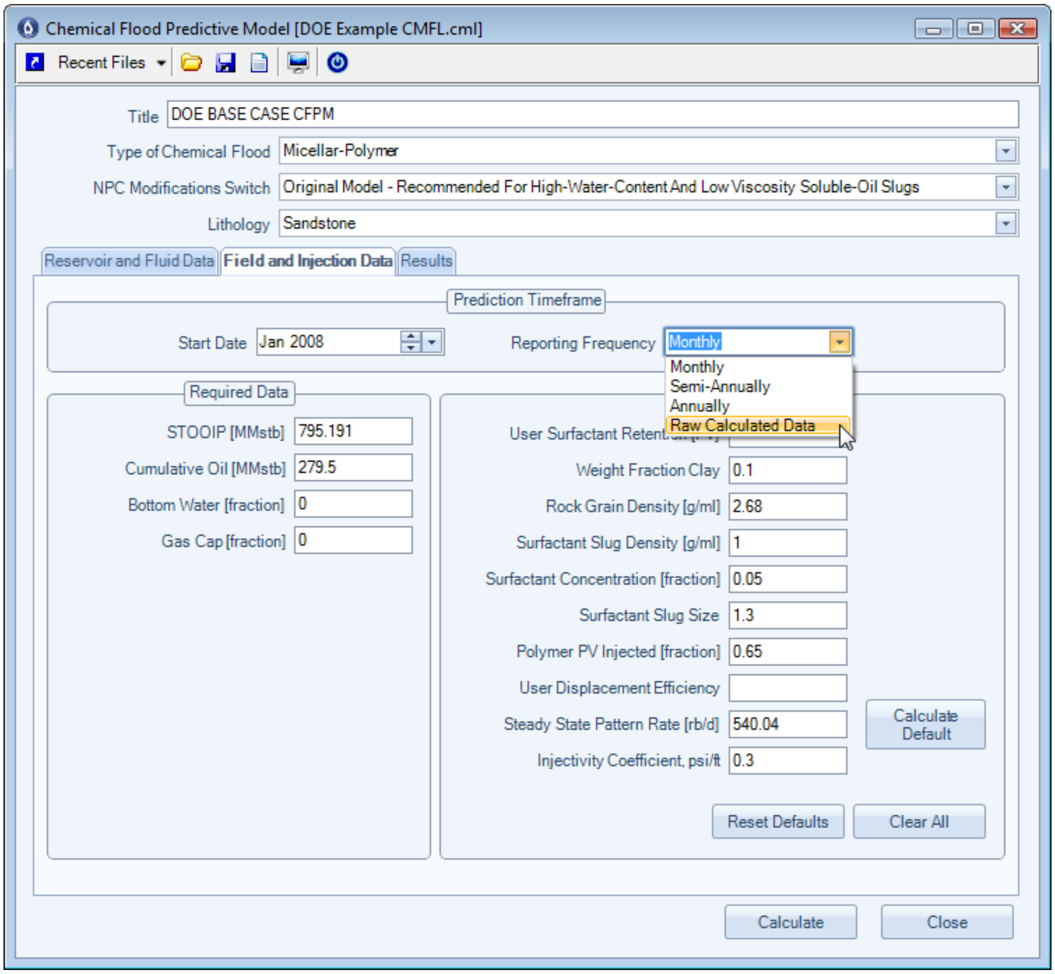
- Complex and expensive systems.
- Possibility of chromatographic separation of chemicals in reservoir.
- High adsorption of surfactant.
- Interactions between surfactant and polymer.
- Degradation of chemicals at high temperature.

The following description is taken from the US Department of Energy Chemical Flooding Predictive Model (CFPM) documentation.

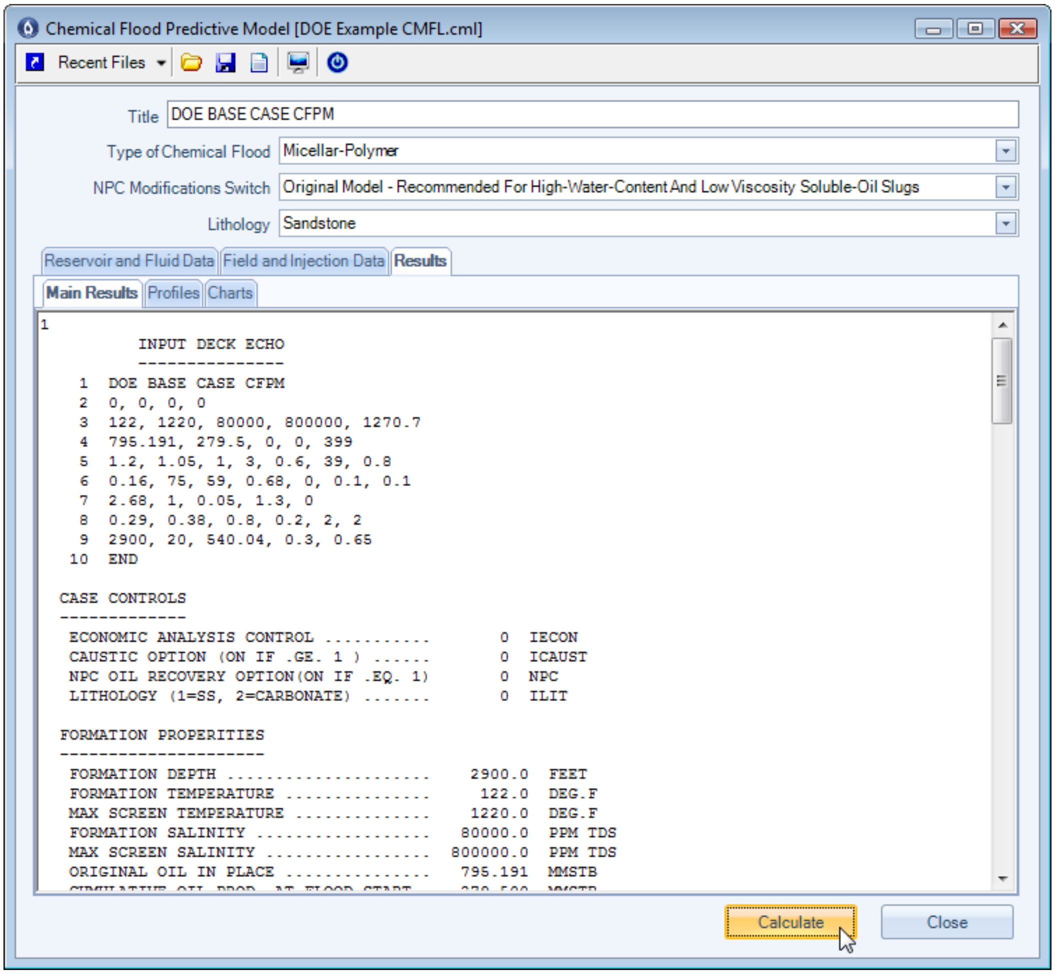
"The CFPM models micellar (surfactant)-polymer (MP) floods in reservoirs which have been previously waterflooded to residual oil saturation. Thus, only true tertiary floods are considered. An option is available in the model which allows a rough estimate of oil recovery by caustic (alkaline) or caustic-polymer processes.

The CFPM uses theory and the results of numerical simulation to predict MP oil recovery in five-spot patterns. Oil-bank and surfactant breakthrough and project life are determined from fractional flow theory. A Koval-type factor, based on the Dykstra-Parsons (1950) coefficient, is used to account for the effects of reservoir heterogeneity on surfactant and oil bank velocities. The overall oil recovery efficiency is the product of the efficiencies for 1-D displacement, vertical sweep of surfactant, and polymer sweep. The displacement efficiency is determined from the capillary number, which is in turn a function of permeability, depth and well spacing. Correlations derived from the results of numerical simulation are used to express vertical sweep efficiency as a function of surfactant slug size, surfactant adsorption and reservoir heterogeneity. The polymer sweep efficiency is an empirical factor developed from numerical simulation and is a function of the polymer slug size and the vertical sweep efficiency. The overall recovery efficiency is corrected for the effects of crossflow by a formula, again developed from the results of numerical simulation, which depends on the ratio of vertical to horizontal permeability."

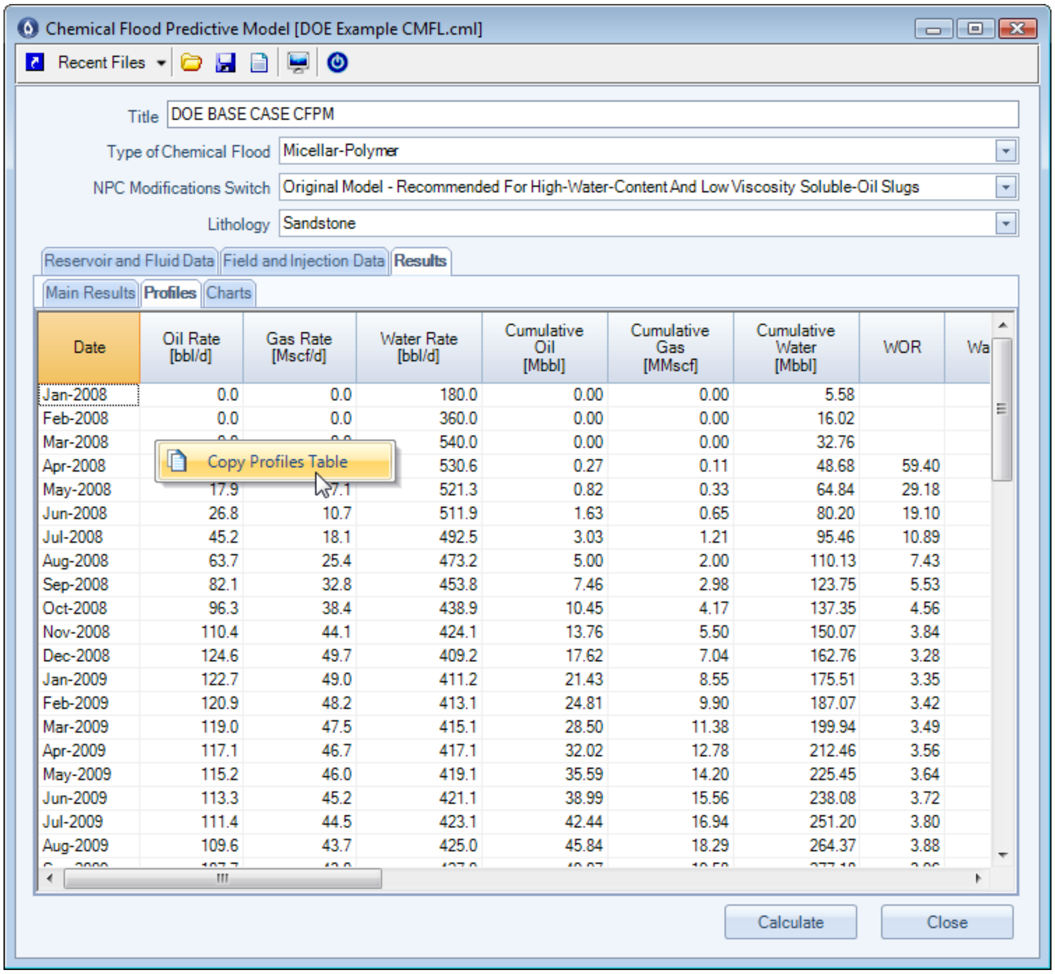




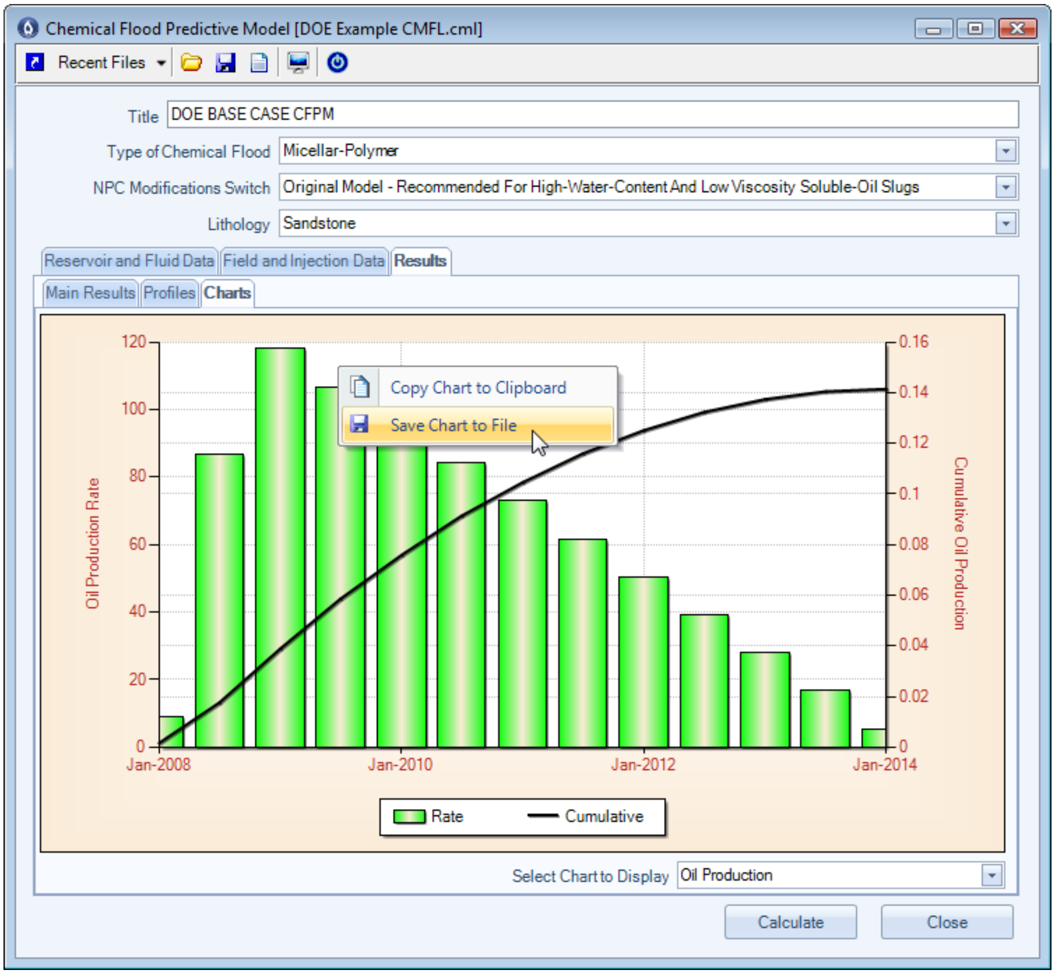
Once the user has pressed the Calculate button, the results data will be re-imported back into the application and displayed as shown in the following three screen captures below.



The user can copy the data from the data tables to the Windows clipboard for use with other applications, such as Microsoft Excel. To display the context menu shown below, simply single right-mouse-click while over the data table.



The user can also copy the active chart to the Windows clipboard for use with other applications, such as Microsoft Powerpoint.

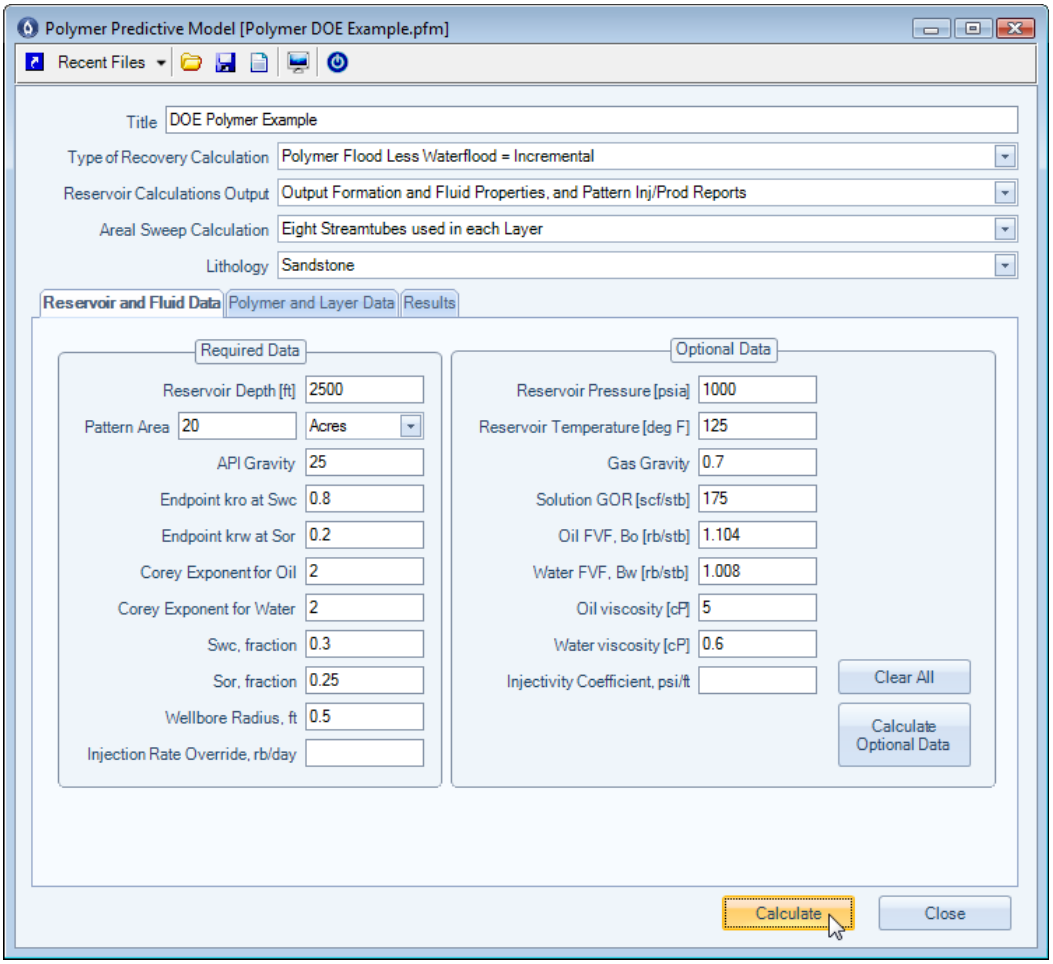


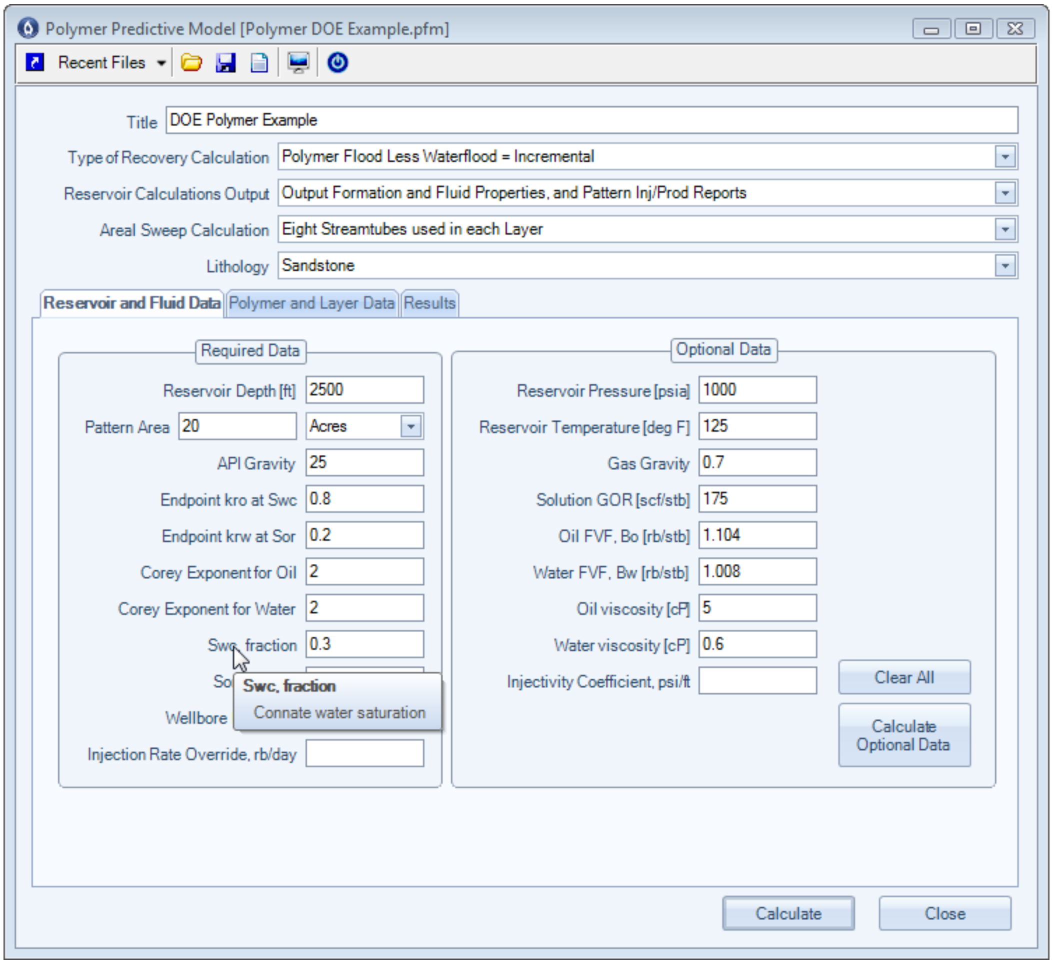
2.4 Polymer Predictive Model

The intent with polymer flooding is to provide better displacement and volumetric sweep efficiencies during a waterflood. This process improves recovery by increasing the viscosity of water, decreasing the mobility of water and contacting a larger volume of the reservoir.

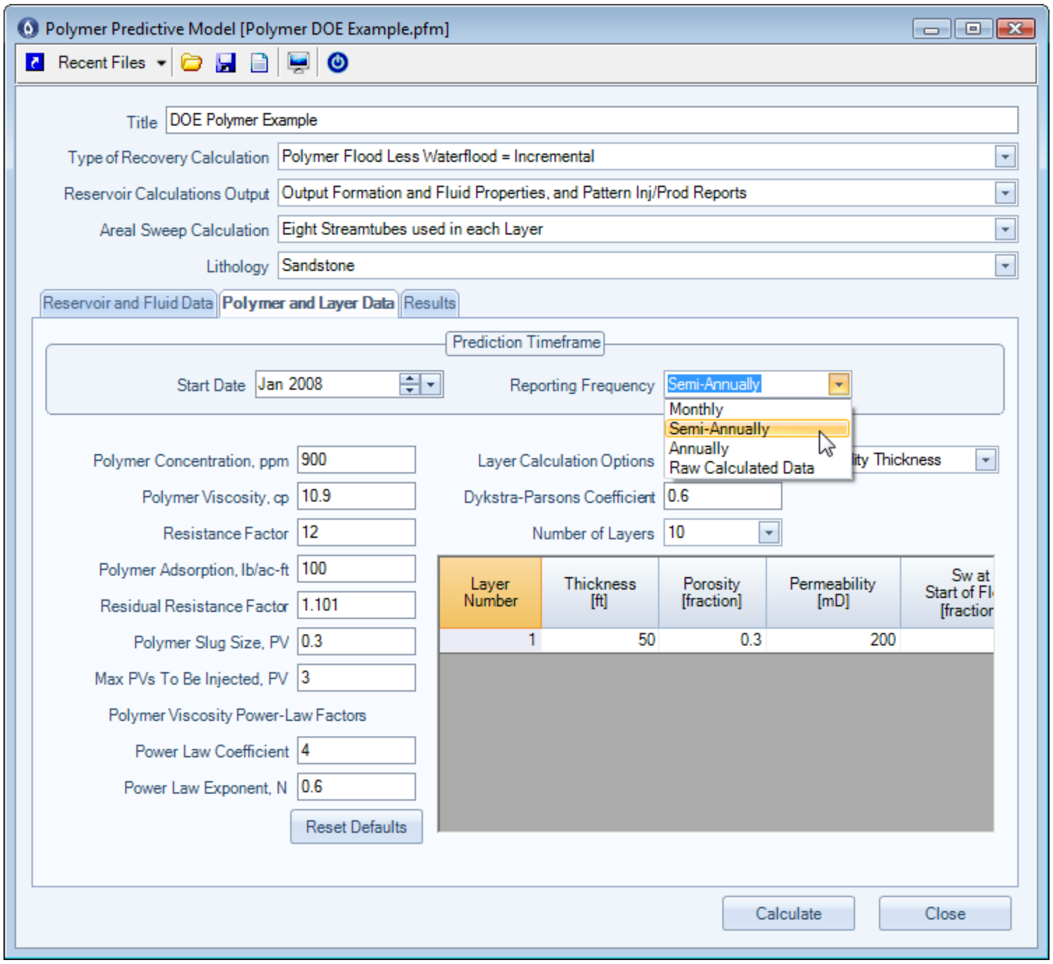
The following description is taken from the US Department of Energy Polymer Flooding Predictive Model (PFPM) documentation.

"The PFPM is switch-selectable for either polymer or water-flooding, and an option in the model allows the calculation of the incremental oil recovery and economics of polymer relative to waterflooding. The PFPM is a three-dimensional (stratified, five-spot), two-phase (water and oil) model which computes water front breakthrough and oil recovery using fractional flow theory, and models areal and vertical sweeps using a streamtube approach. A correlation based on numerical simulation results is used to model the polymer slug size effect. The physical properties of polymer fluids, such as adsorption, permeability reduction, and non-Newtonian effects, are included in the model. Pressure drop between the injector and producer is kept constant, and the injectivity at each time step is calculated based on the mobility in each streamtube. Heterogeneity is accounted for by either entering detailed layer data or using the Dykstra-Parsons coefficient for a reservoir with a log-normal permeability distribution."


Polymer Predictive Model [Polymer DOE Example.pfm]
Recent Files
Title
DOE Polymer Example
Type of Recovery Calculation
Polymer Flood Less Waterflood = Incremental
Reservoir Calculations Output
Output Formation and Fluid Properties, and Pattern Inj/Prod Reports
Areal Sweep Calculation
Eight Streamtubes used in each Layer
Lithology
Sandstone
Reservoir and Fluid Data
Polymer and Layer Data
Results
Required Data
Reservoir Depth [ft] 2500
Pattern Area 20 Acres
API Gravity 25
Endpoint kro at Swc 0.8
Endpoint krw at Sor 0.2
Corey Exponent for Oil 2
Corey Exponent for Water 2
Swc, fraction 0.3
Sor, fraction 0.25
Wellbore Radius, ft 0.5
Injection Rate Override, rb/day
Optional Data
Reservoir Pressure [psia] 1000
Reservoir Temperature [deg F] 125
Gas Gravity 0.7
Solution GOR [scf/stb] 175
Oil FVF, Bo [rb/stb] 1.104
Water FVF, Bw [rb/stb] 1.008
Oil viscosity [cP] 5
Water viscosity [cP] 0.6
Injectivity Coefficient, psi/ft
Clear All
Calculate Optional Data
Calculate
Close



Tooltips, as shown above, are provided to help define some of the input data requirements. To display these tooltips simply hover the mouse over the label box describing the input data.



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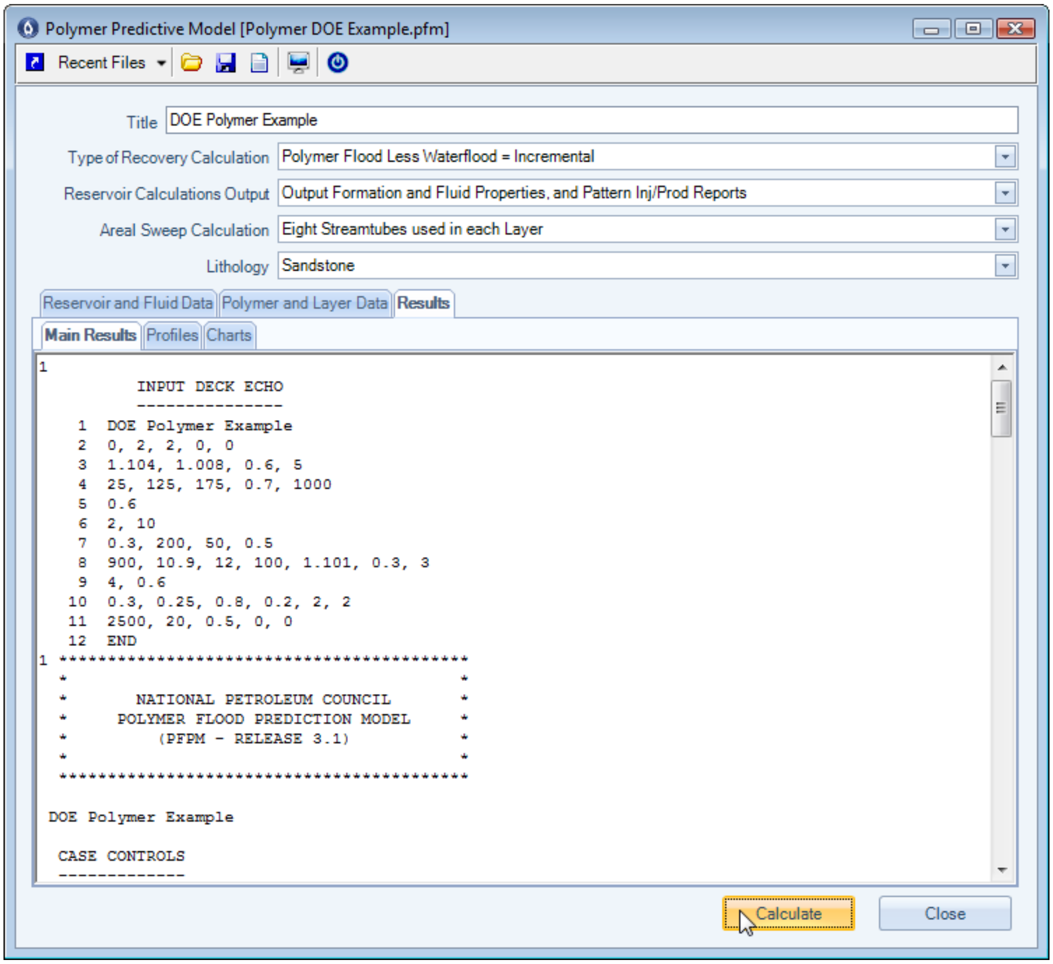

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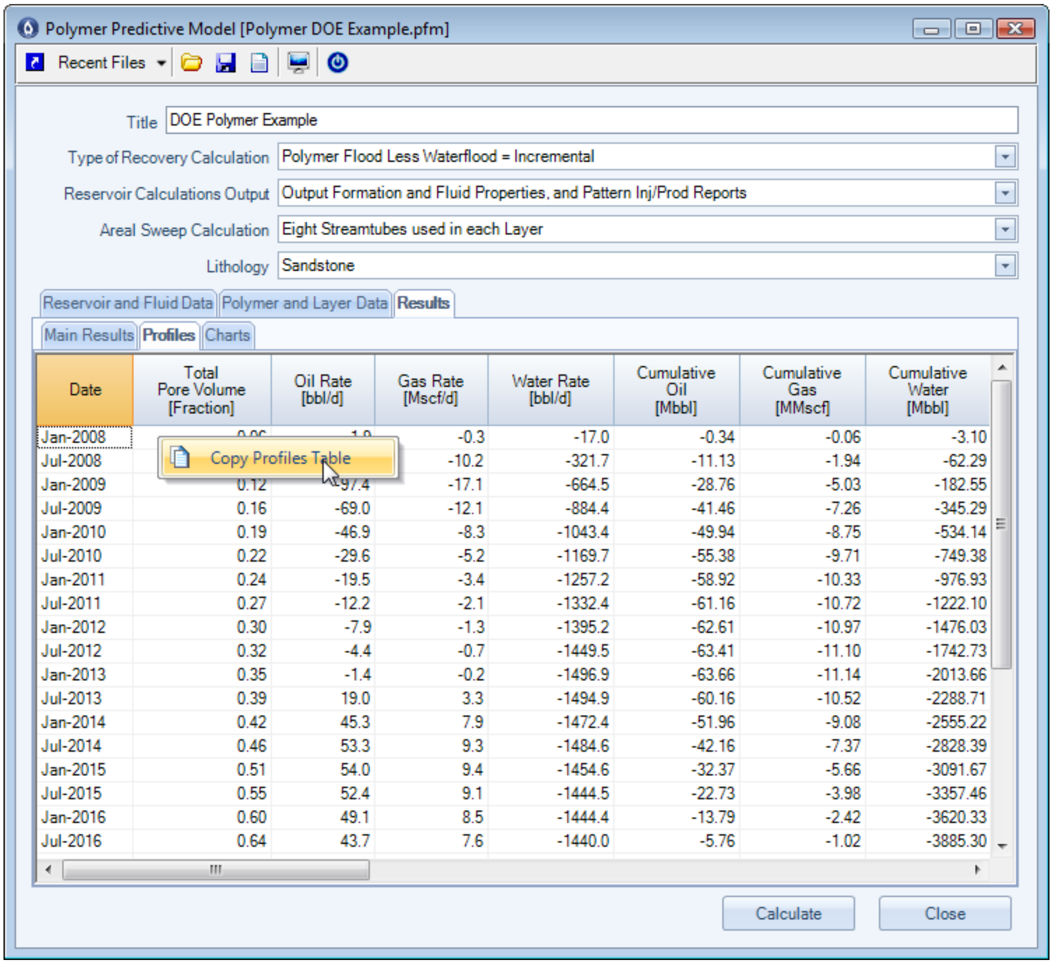
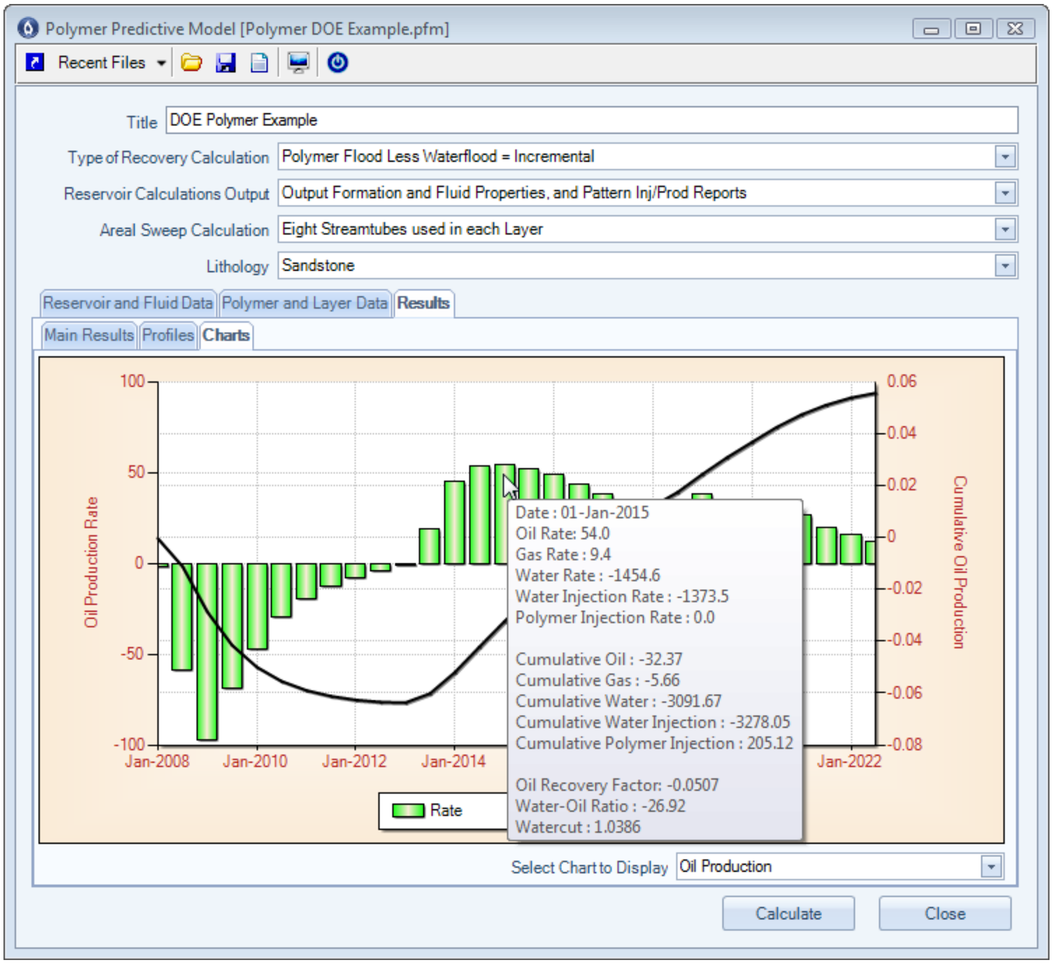


The user can also copy the active chart to the Windows clipboard for use with other applications, such as Microsoft Powerpoint. Data tooltips can also be displayed within the chart area by hovering the mouse over a series datapoint, as shown below.



2.5 In-situ Combustion Predictive Model

In-situ combustion involves starting a fire in the reservoir and injecting air to sustain the burning of some of the crude oil. This process recovers oil by the application of heat to lower the oil viscosity, upgrading the crude through thermal cracking, and the pressure supplied to the reservoir by the injected air.

Limitations

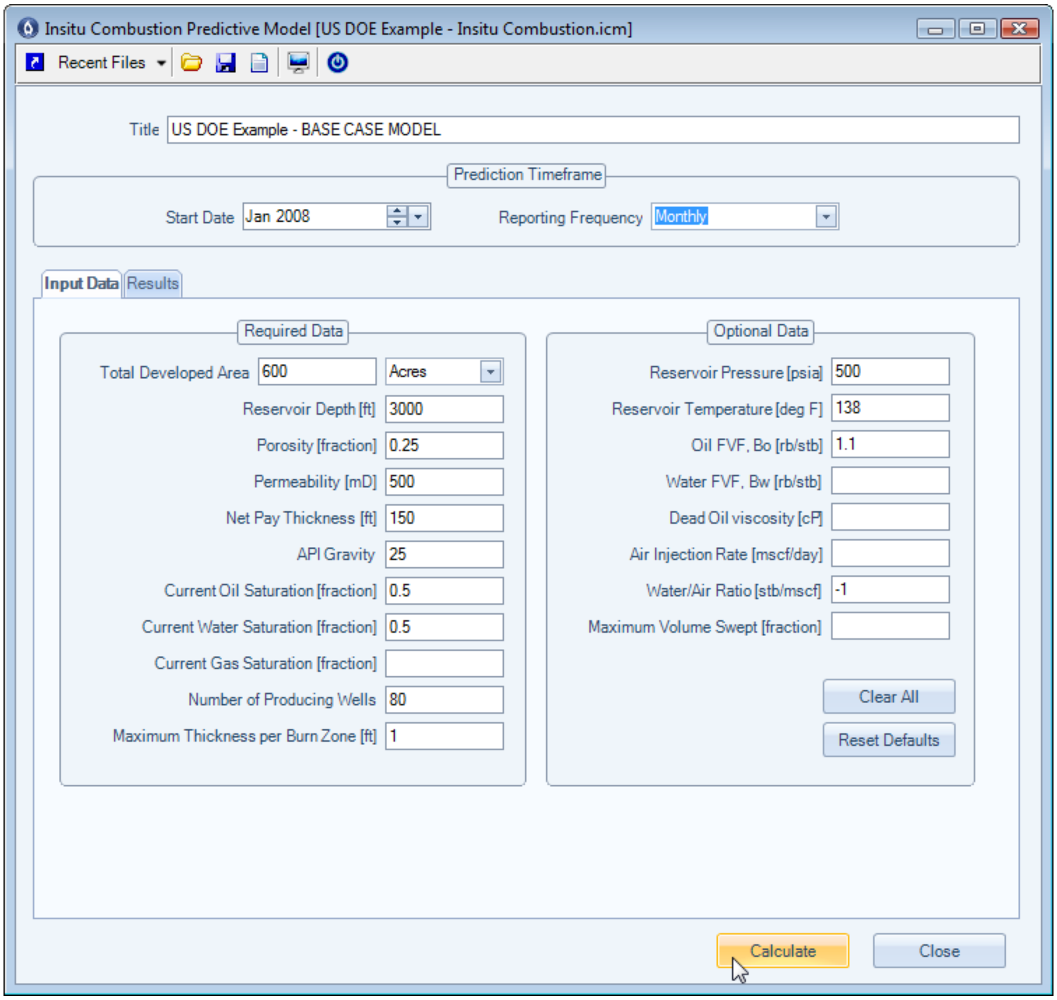
- If sufficient coke is not deposited from the oil being burned, the combustion process will not be sustained. This prevents the application for high-gravity, paraffinic oils.
- If excessive coke is deposited, the rate of advance of the combustion zone will be slow, and the quantity of air required to sustain combustion will be high.
- Oil saturation and porosity must be high to minimize heat loss to rock,
- Process tends to sweep through upper part of reservoir so that sweep efficiency is poor in thick formation.

Problems

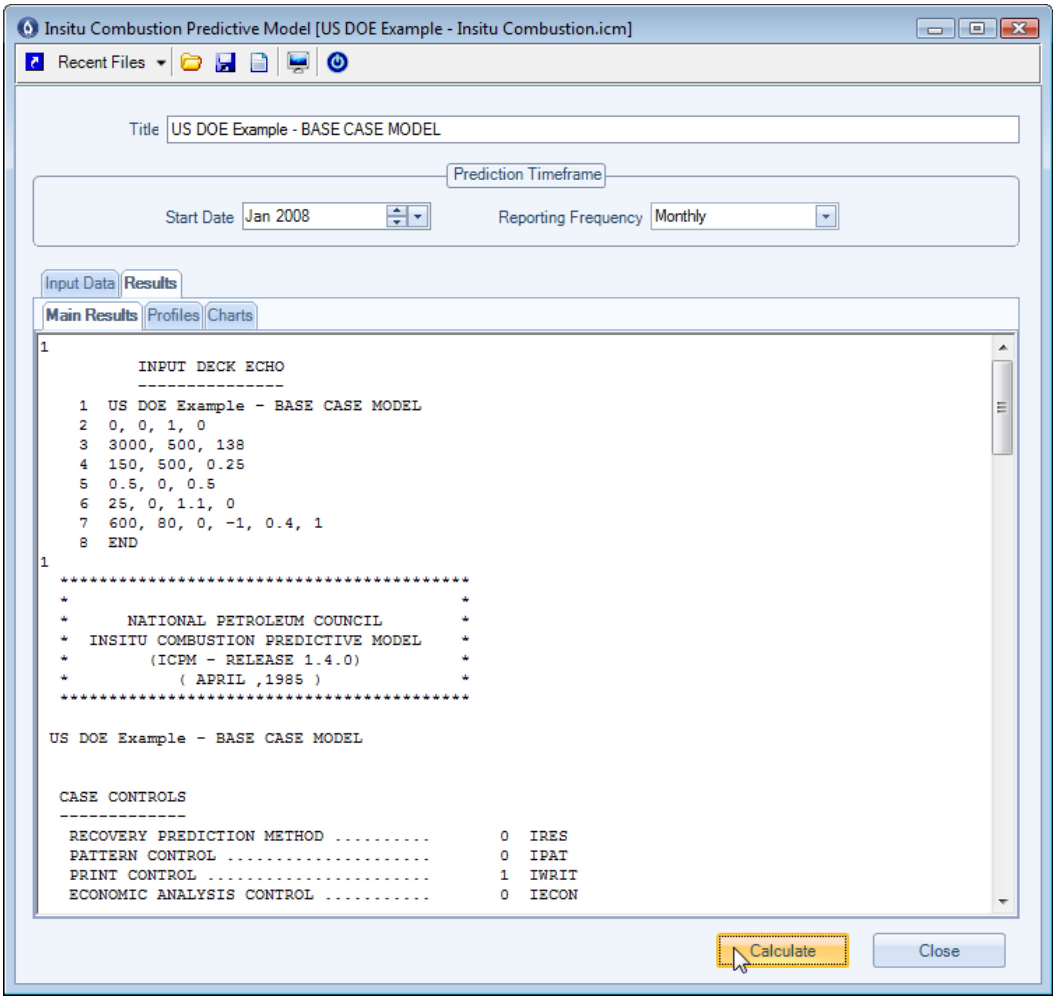
- Adverse mobility ratio.
- Complex process, requiring large capital investment, is difficult to control.
- Produced flue gases can present environmental problems.
- Operational problems such as severe corrosion caused by low pH hot water, serious oil-water emulsions, increased sand production, deposition of carbon or wax, and pipe failures in the producing wells as a result of the very high temperatures.

The following description is taken from the US Department of Energy Insitu Combustion Predictive Model (ICPM) documentation.

"The ICPM oil recovery algorithm is based on the work of Brigham, et al (1980), who correlated the major variables in the combustion process to the results of 12 field pilot tests. Their correlation relates oil burned and oil produced to the amount of air injected and the reservoir volume, and is for dry combustion only. A method to predict wet combustion performance was added by NPC based on laboratory data (Garon and Wygal, 1974; Prats, 1982)."



Once the user has pressed the Calculate button, the results data will be re-imported back into the application and displayed as shown in the following three screen captures below.



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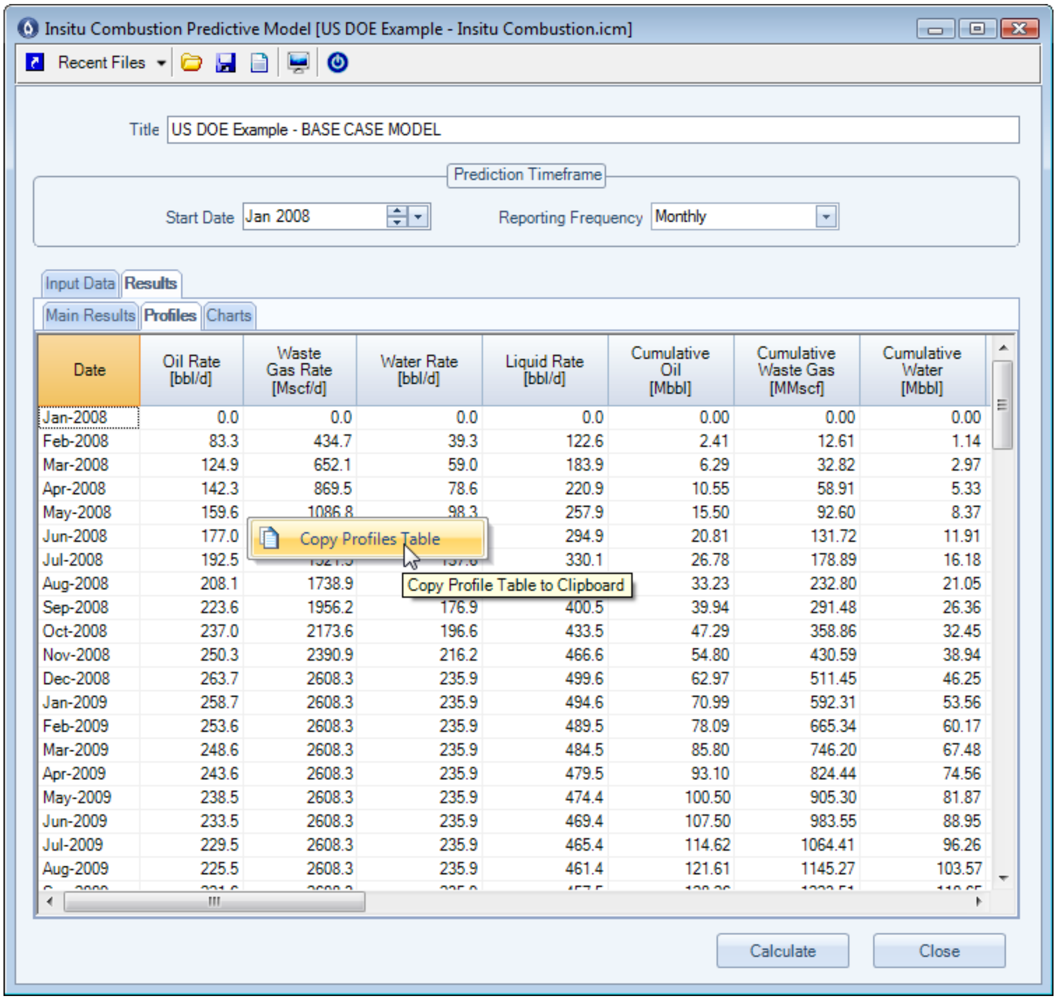
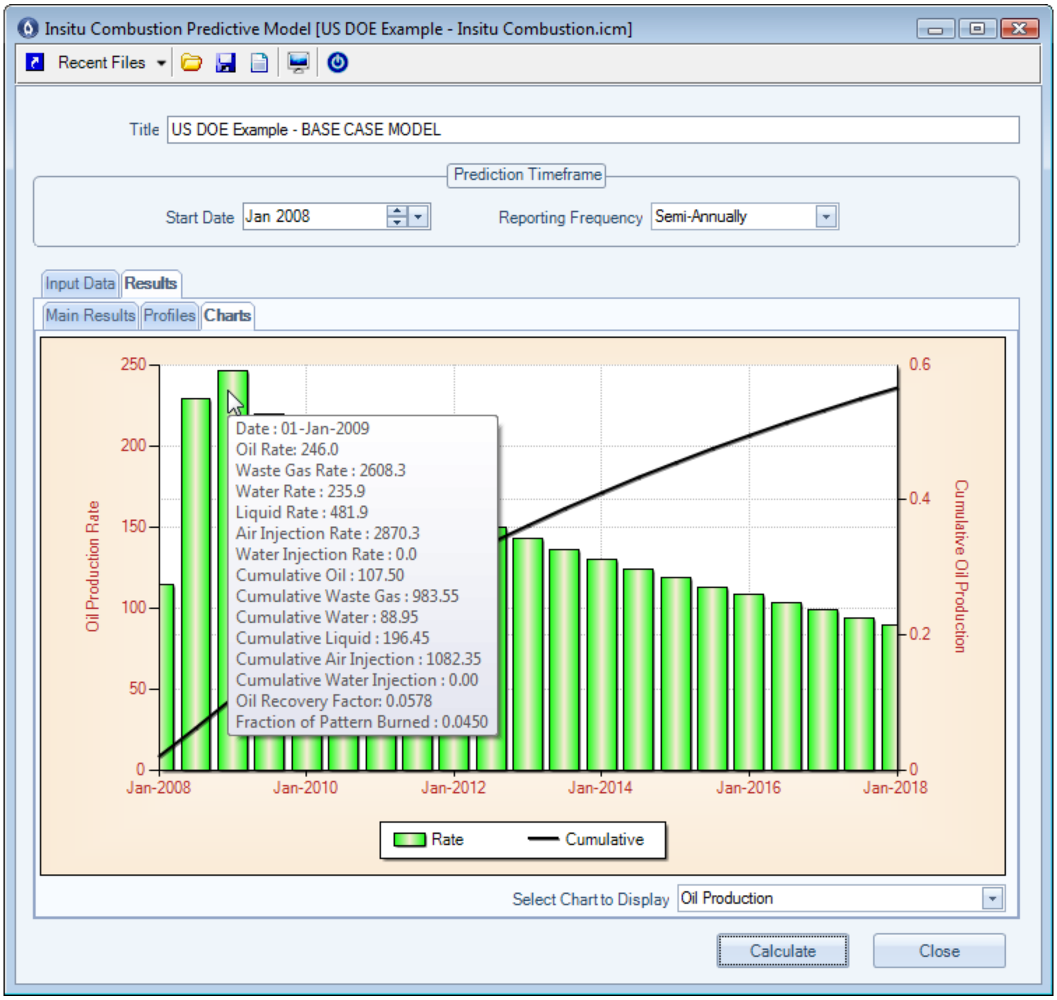


The user can also copy the active chart to the Windows clipboard for use with other applications, such as Microsoft Powerpoint. Data tooltips can also be displayed within the chart area by hovering the mouse over a series datapoint, as shown below.



2.6 Steamflood Predictive Model

The steamdrive process or steamflooding involves the continuous injection of steam to displace oil towards the producing wells. This process recovers oil by heating the oil and reducing it's viscosity, supplying pressure to drive oil to the producing wells and steam distillation, especially in light crude oils.

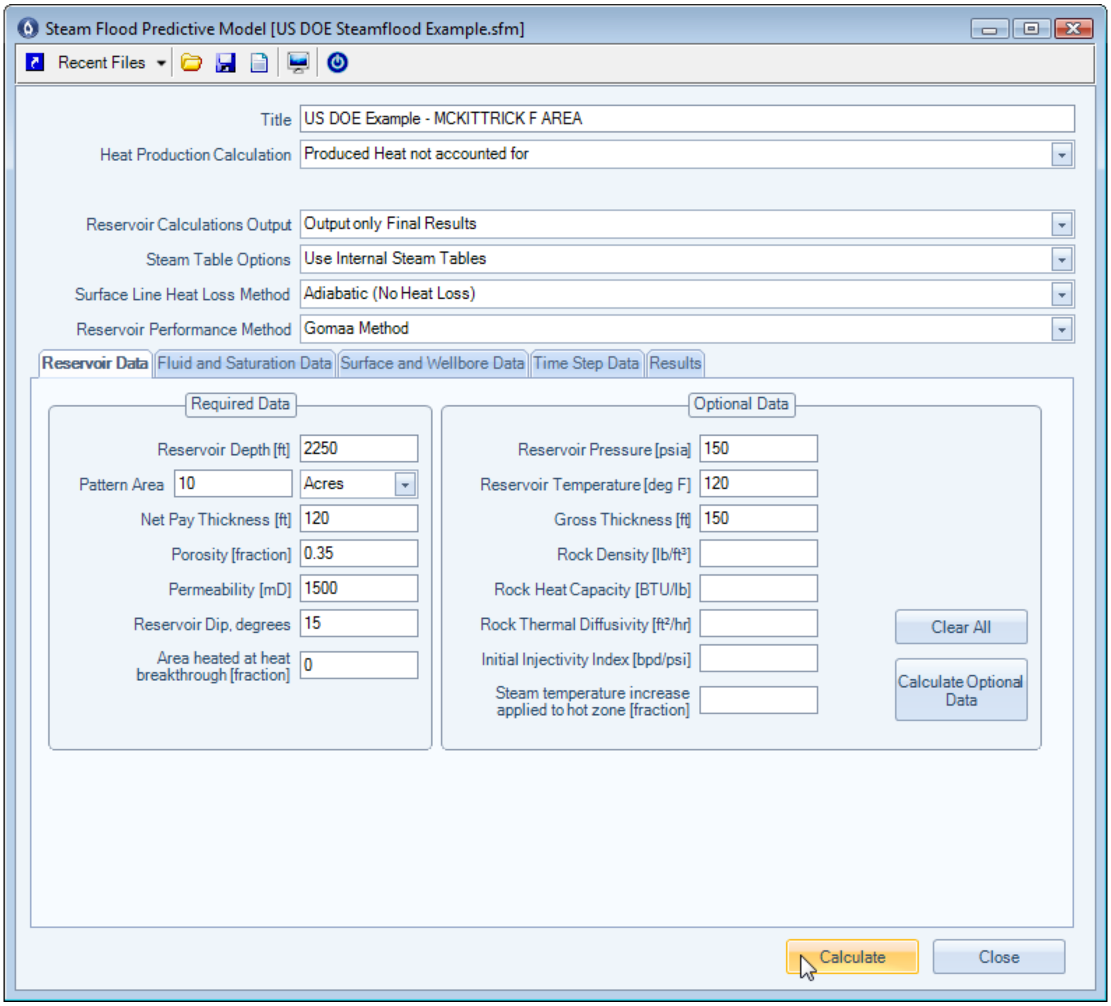
Limitations

- Oil saturations must be quite high and the pay zone should be more than 20 feet thick to minimize heat losses to adjacent formations.
- Lighter, less viscous crude oils can be steamflooded but normally will not be if the reservoir will respond to an ordinary waterflood.
- Steamflooding is primarily applicable to viscous oils in massive, high-permeability sandstones or unconsolidated sands.
- Because of excess heat losses in the wellbore, steamflooded reservoirs should be as shallow as possible as long as pressure for sufficient injection rates can be maintained.
- Steamflooding is not normally used in carbonate reservoirs.
- Since about one-third of the additional oil recovered is consumed to generate the required steam, the cost per incremental barrel of oil is high.
- A low percentage of water-sensitive clays is desired for good injectivity.

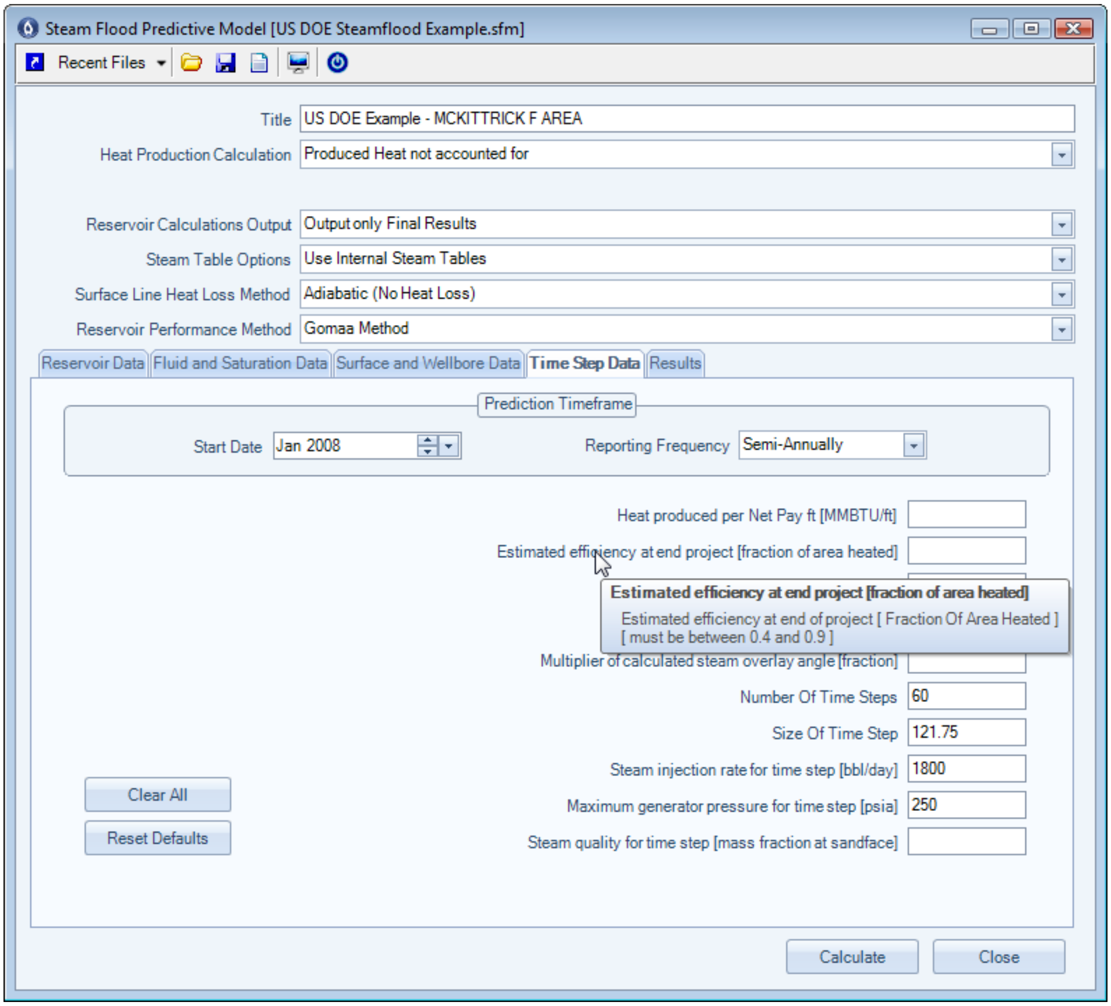
The following description is taken from the US Department of Energy Steamflood Predictive Model

(SFPM) documentation.

"The SFPM is applicable to the steam drive process, but not to cyclic steam injection (steam soak) processes. There are four separate oil recovery predictive algorithms in the SFPM: the Williams et al (1980) model, also known as the Stanford University Petroleum Research Institute (SUPRI) model, the Jones (1981) model, the Gomaa (1980) model, and the Intercomp model (Aydelotte and Pope, 1983). All of the predictive algorithms in the SFPM make use of calculations for heat losses in surface pipe and in the wellbore, as originally presented by Williams et al (1980)."



Tooltips, as shown below, are provided to help define some of the input data requirements. To display these tooltips simply hover the mouse over the label box describing the input data.



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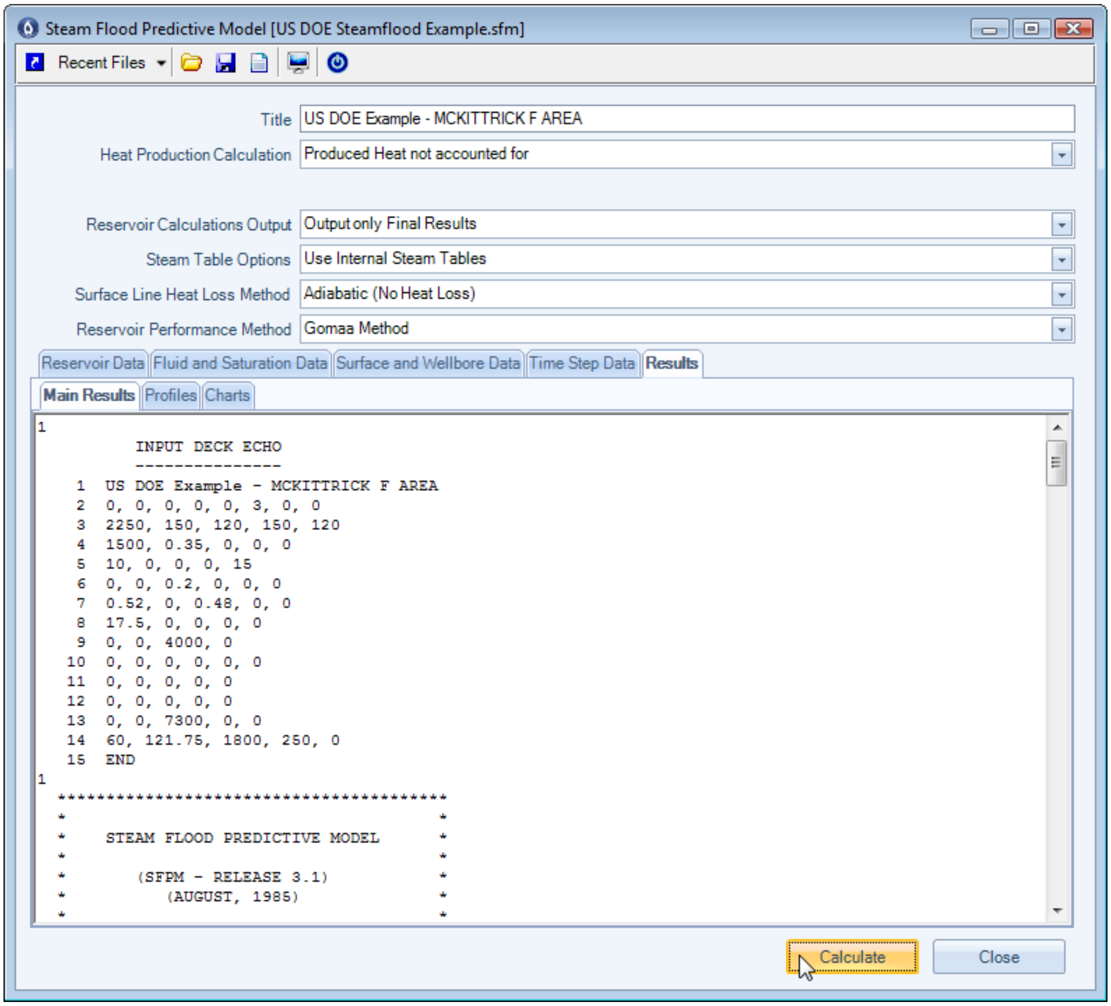

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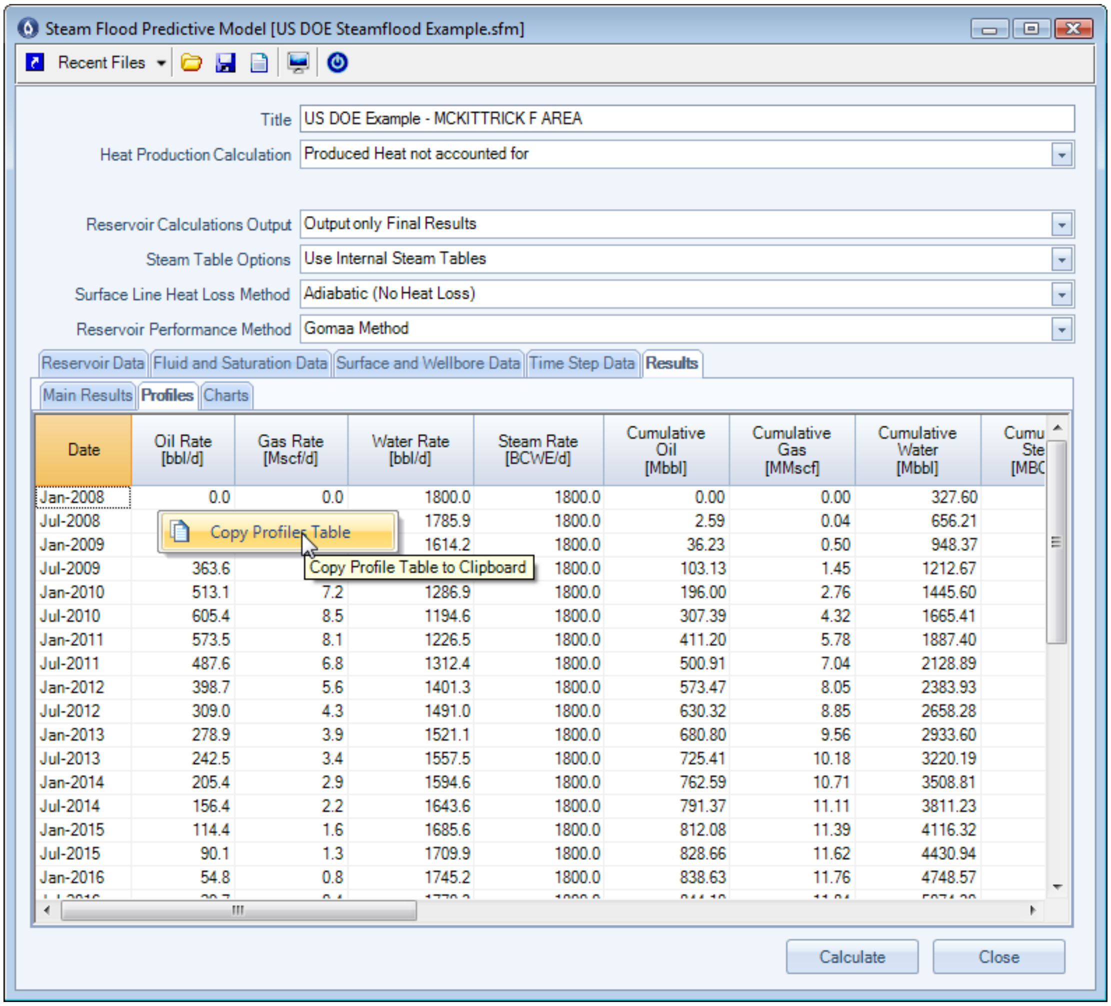
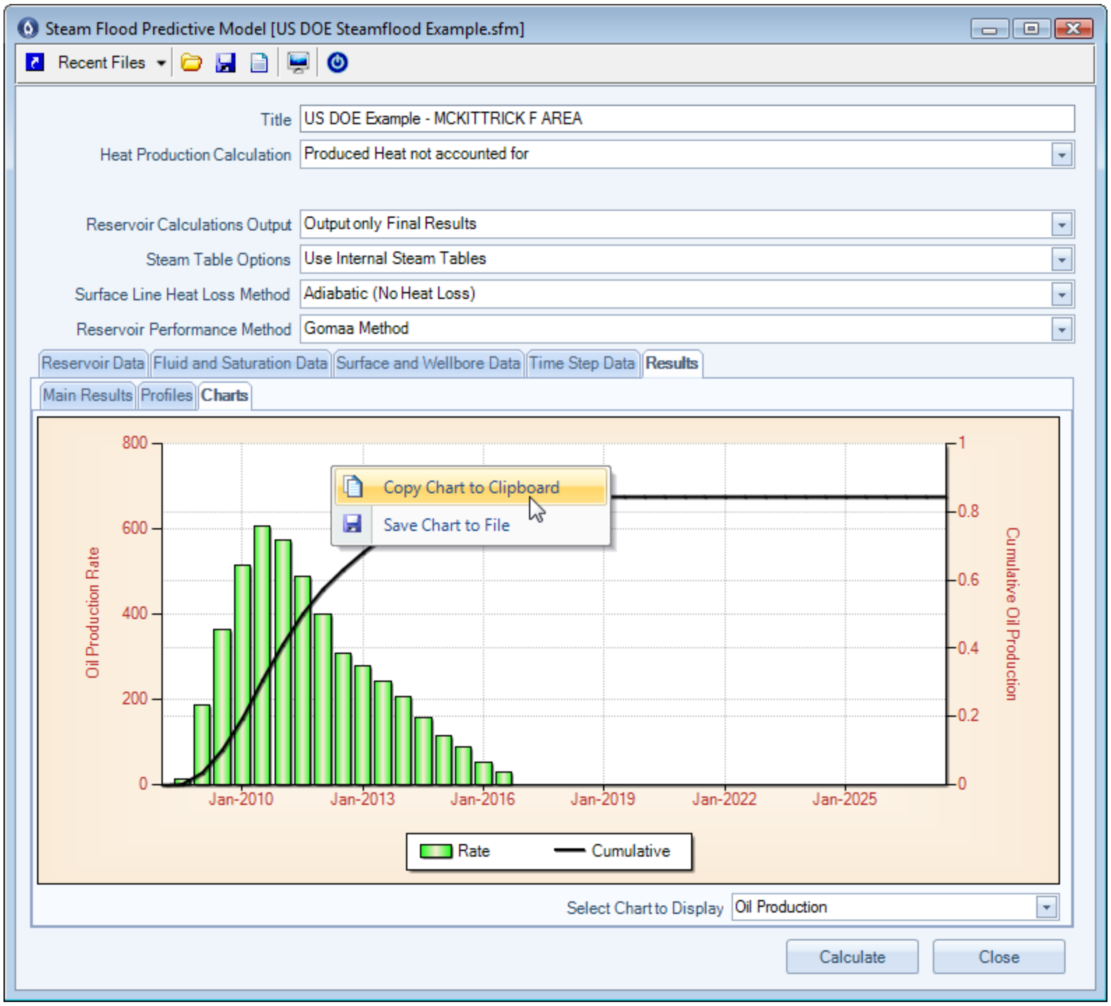


Date	Oil Rate [bbl/d]	Gas Rate [Mscf/d]	Water Rate [bbl/d]	Steam Rate [BCWE/d]	Cumulative Oil [Mbbl]	Cumulative Gas [MMscf]	Cumulative Water [Mbbl]	Cumu Ste [MBC
Jan-2008	0.0	0.0	1800.0	1800.0	0.00	0.00	327.60	
Jul-2008			1785.9	1800.0	2.59	0.04	656.21	
Jan-2009			1614.2	1800.0	36.23	0.50	948.37	
Jul-2009	363.6			1800.0	103.13	1.45	1212.67	
Jan-2010	513.1	7.2	1286.9	1800.0	196.00	2.76	1445.60	
Jul-2010	605.4	8.5	1194.6	1800.0	307.39	4.32	1665.41	
Jan-2011	573.5	8.1	1226.5	1800.0	411.20	5.78	1887.40	
Jul-2011	487.6	6.8	1312.4	1800.0	500.91	7.04	2128.89	
Jan-2012	398.7	5.6	1401.3	1800.0	573.47	8.05	2383.93	
Jul-2012	309.0	4.3	1491.0	1800.0	630.32	8.85	2658.28	
Jan-2013	278.9	3.9	1521.1	1800.0	680.80	9.56	2933.60	
Jul-2013	242.5	3.4	1557.5	1800.0	725.41	10.18	3220.19	
Jan-2014	205.4	2.9	1594.6	1800.0	762.59	10.71	3508.81	
Jul-2014	156.4	2.2	1643.6	1800.0	791.37	11.11	3811.23	
Jan-2015	114.4	1.6	1685.6	1800.0	812.08	11.39	4116.32	
Jul-2015	90.1	1.3	1709.9	1800.0	828.66	11.62	4430.94	
Jan-2016	54.8	0.8	1745.2	1800.0	838.63	11.76	4748.57	

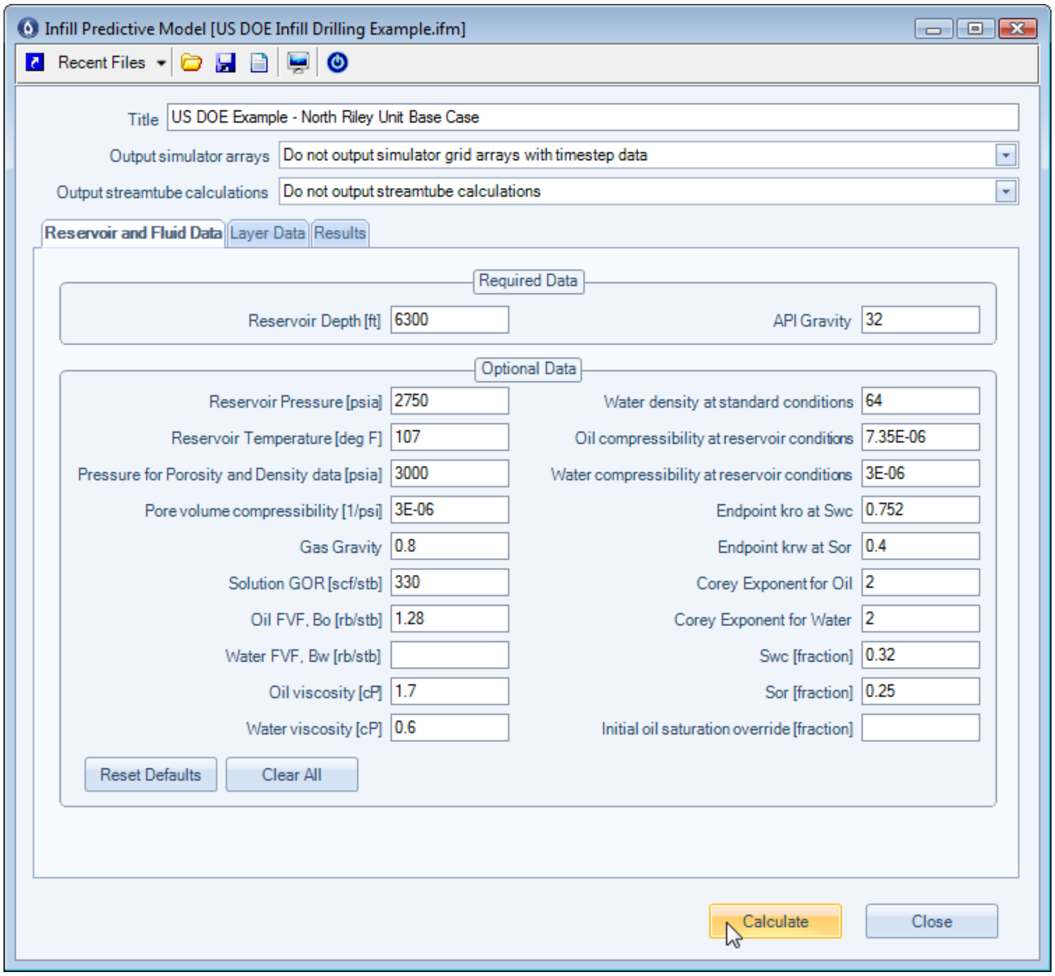
The user can also copy the active chart to the Windows clipboard for use with other applications, such as Microsoft Powerpoint.



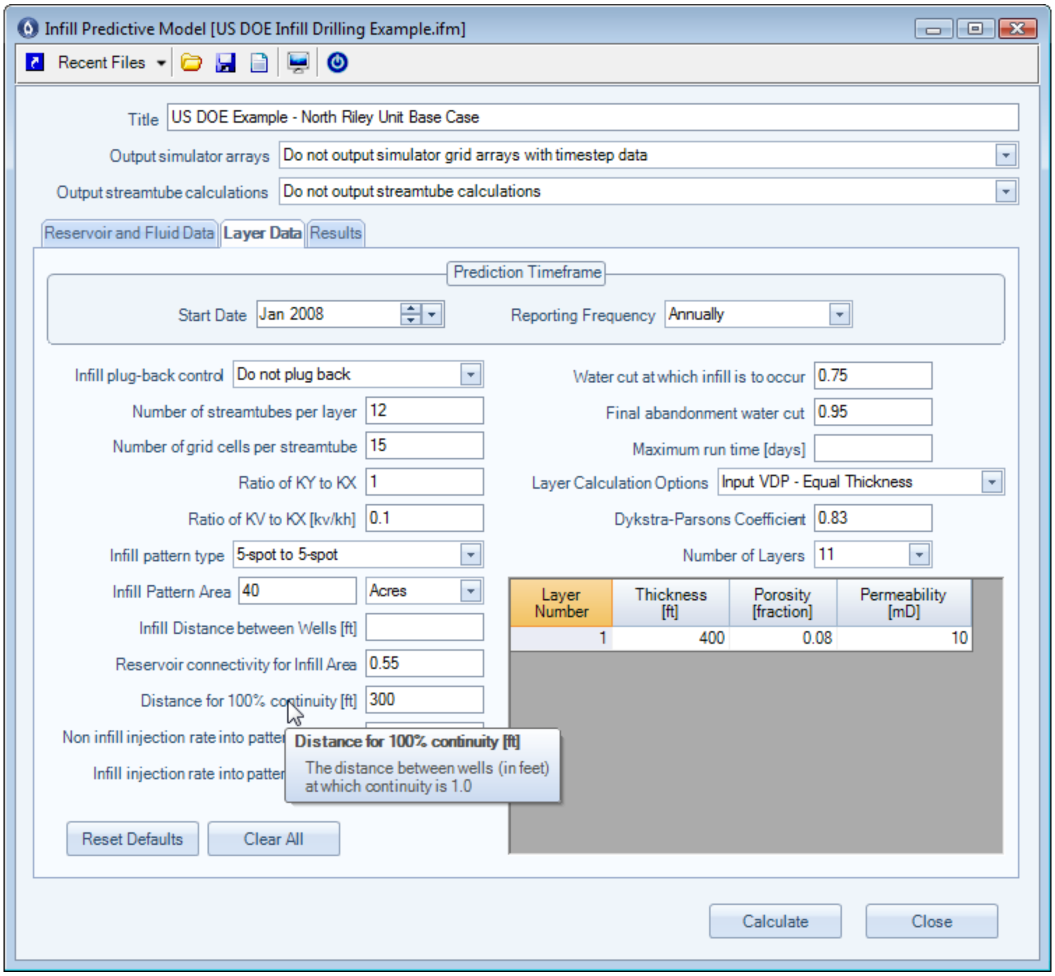
2.7 Infill Drilling Predictive Model

The following description is taken from the US Department of Energy Infill Drilling Predictive Model (IDPM) documentation.

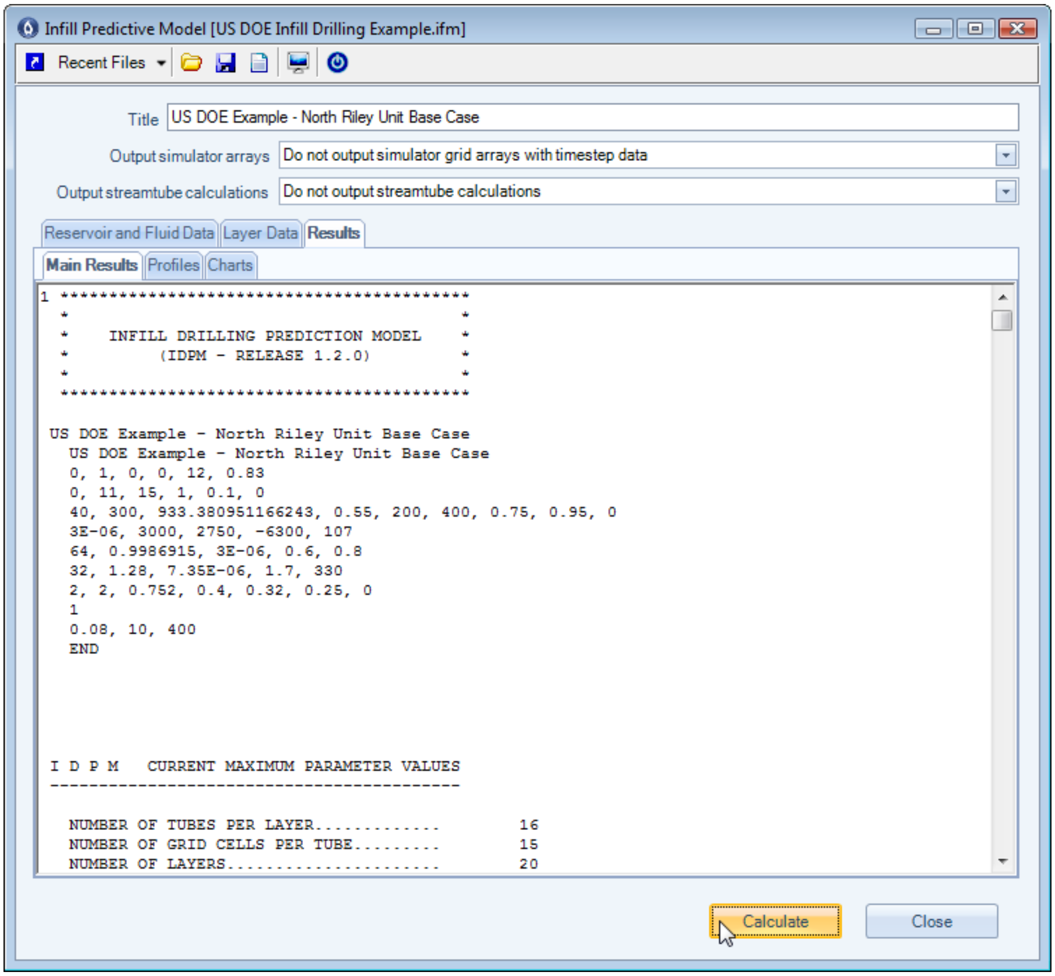
"The IDPM is a three-dimensional (stratified, five-spot), two-phase (oil and water) model which uses a minimal amount of reservoir and geologic data to generate production and recovery forecasts for ongoing waterflood and infill drilling projects. The model computes water-oil displacement and oil recovery using finite difference solutions within streamtubes. It calculates the streamtube geometries and uses a two-dimensional reservoir simulation to track fluid movement in each streamtube slice."



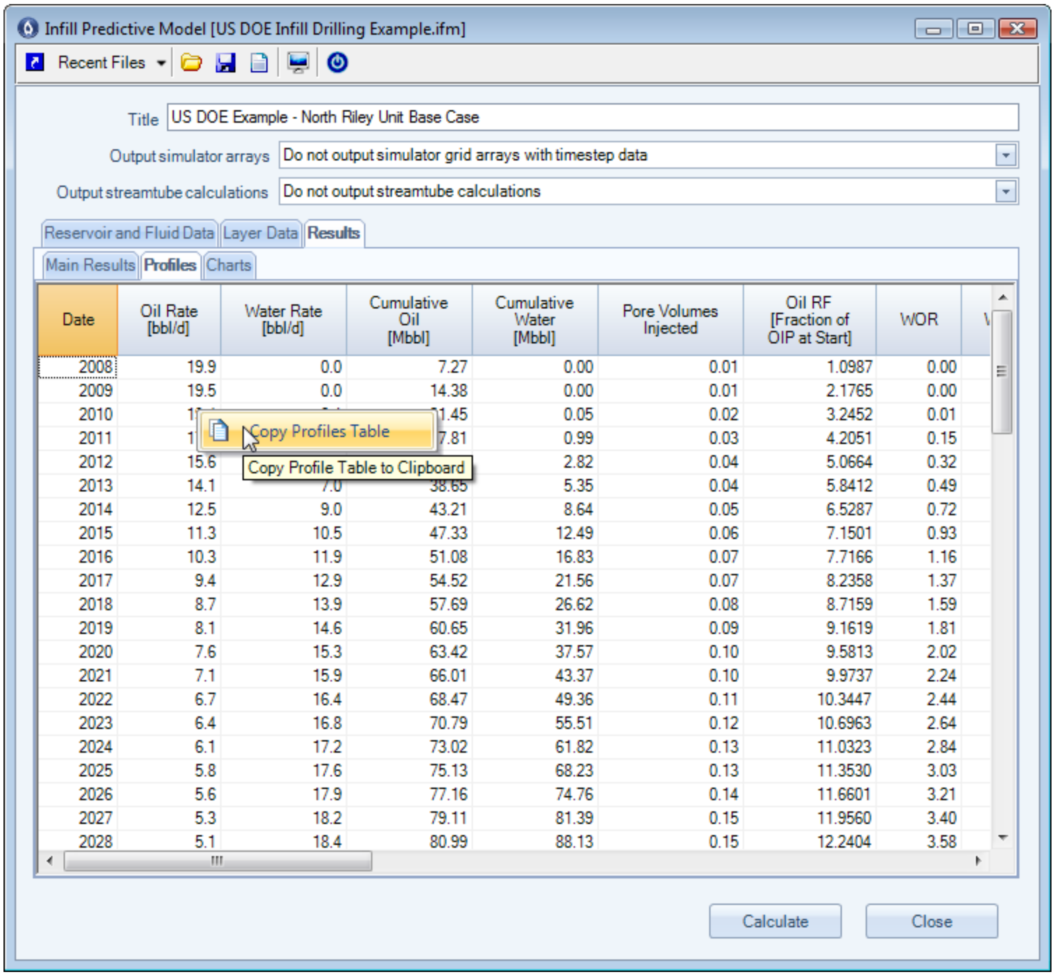
Tooltips, as shown below, are provided to help define some of the input data requirements. To display these tooltips simply hover the mouse over the label box describing the input data.



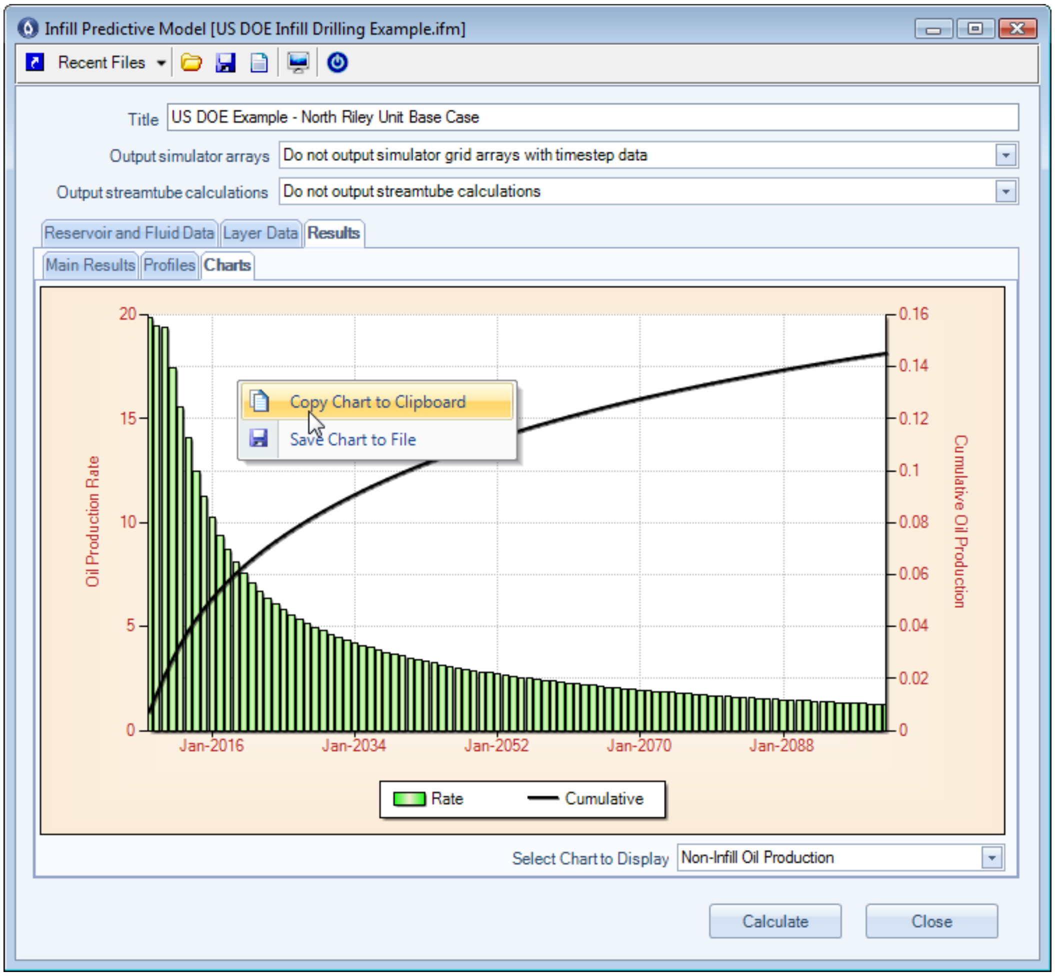
Once the user has pressed the Calculate button, the results data will be re-imported back into the application and displayed as shown in the following three screen captures below.



The user can copy the data from the data tables to the Windows clipboard for use with other applications, such as Microsoft Excel. To display the context menu shown below, simply single right-mouse-click while over the data table.



The user can also copy the active chart to the Windows clipboard for use with other applications, such as Microsoft Powerpoint.



2.8 Example Data Files

Contained within the installation process are example data files for each of the application modules.

These files can be found in a sub-folder of the Application installation folder, and is typically called :

C:\Program Files\Petroleum Solutions\EORgui\Examples\

The user can browse to this folder within the application to see how input is formatted and to trial the functionality of the various modules.

An example screen capture of one one these files is shown below.

```xml
<PolymerFlood_Data>
    <Title>DOE Polymer Example</Title>
    <IOPT>2</IOPT>
    <IAROPT>2</IAROPT>
    <ILIT>0</ILIT>
    <BO>1.104</BO>
    <BW>1.008</BW>
    <VISO>5</VISO>
    <VISW>0.6</VISW>
    <API>25</API>
    <TEMP>125</TEMP>
    <GOR>175</GOR>
    <SGG>0.7</SGG>
    <PFORM>1000</PFORM>
    <LYROPT>2</LYROPT>
    <VDP>0.6</VDP>
    <NLAYER>10</NLAYER>
    <ThicknessString>50,0,0,0,0,0,0,0,0,0</ThicknessString>
    <PoroString>0.3,0,0,0,0,0,0,0,0,0</PoroString>
    <PermString>200,0,0,0,0,0,0,0,0,0</PermString>
    <SwcString>0.5,0,0,0,0,0,0,0,0,0</SwcString>
    <CONCP>900</CONCP>
    <VISP>10.9</VISP>
    <RF>12</RF>
    <DSPAF>100</DSPAF>
    <RRF>1.101</RRF>
    <VPMB>0.3</VPMB>
    <VIMAX>3</VIMAX>
    <XKPL>4</XKPL>
    <XNPL>0.6</XNPL>
    <SWC>0.3</SWC>
    <SORW>0.25</SORW>
    <XKROE>0.8</XKROE>
    <XKRWE>0.2</XKRWE>
    <XNO>2</XNO>
    <XNW>2</XNW>
    <DEPTH>2500</DEPTH>
    <AREA>20</AREA>
    <AreaUnits>0</AreaUnits>
    <RW>0.5</RW>
    <CP>0</CP>
    <QRES>0</QRES>
    <StartDate>01/01/2008 00:00:00</StartDate>
    <CalcFrequency>1</CalcFrequency>
</PolymerFlood_Data>
```

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