



# LYNX<sup>®</sup>

LYNX<sup>®</sup> makes the history matching (HM) of reservoir simulation models faster, more reliable, easier, and more accurate while assuring consistency between the interpreted and refined source data and the simulation model. LYNX provides the asset team with powerful analysis aids to facilitate the interactive HM process. Engineers have carried out history matching through simulation for over 40 years. LYNX now provides the engineer with a tool that significantly streamlines and accelerates the history matching process.

LYNX evolved out of the need in NITEC LLC's consulting operations to do a better job of integrating and evaluating data as a part of the reservoir simulation process. Reservoir simulators were getting faster, but the process of interpreting data, building simulation models, and conducting the history match was not. LYNX addresses this need and much more.

NITEC has conducted all of its reservoir studies (black-oil, compositional, single and dual porosity) for clients throughout the world using LYNX since 1997.

## Benefits of LYNX

- Aids data integration
- Provides single project database
- Utilizes numerous data compatibility checks
- Consolidates pre- and post- processing capabilities
- Speeds simulation model development
- Interfaces with numerous simulators
- Provides unique history matching tools requiring limited user intervention
- Finds Multiple, Acceptable HM Solutions
- Reduces simulation runs and analysis time

Developing and history matching reservoir models is data intensive requiring petrophysics, geology, production, fluid, and rock information to be processed and interpreted into a coherent geologic and simulation model of the reservoir. A reservoir simulator is then used to test this model against actual performance data (fluid rates, pressures, and concentrations). Inconsistencies in the simulation model versus actual performance must be reconciled and adjustments made to the reservoir model.

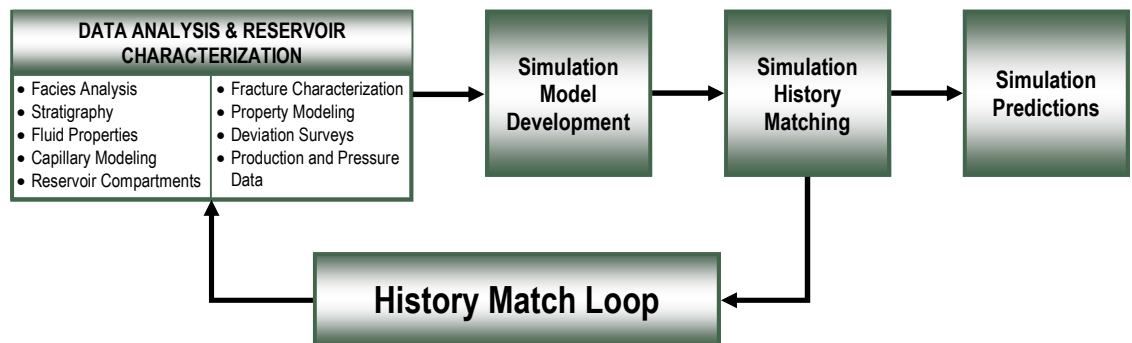
LYNX provides the practical tools and a workflow to review and resolve these inconsistencies quickly and to make the necessary adjustments in a manner that is consistent with all other relevant data. This is achieved by the property modification facilities that substantially eliminate the manual editing of the simulation data set.

LYNX is designed with a complementary set of tools for interacting with commercial

simulators to make the simulation process more efficient. It is capable of creating data sets for various simulators.

LYNX has powerful pre- and post- processing capabilities along with unique simulation input and output data analysis technologies. Some of these technologies, such as HM "mismatch" maps, comparison of multiple HM cases, polygon picking to create well groups, rigorous utilization of RFT and PLT data, and the unique *MatchingPro* technology provide a powerful guide to assist the engineer in closing the history match gap.

The requirements of interpreting data, consolidating it into a reservoir model, and carrying out the interactive history matching process are divided into several areas in LYNX. Functionality for these areas is separated into Data Analysis, Reservoir Characterization, Reservoir Engineering, Simulation Model Development, and Simulation History Matching.



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## DATA ANALYSIS AND RESERVOIR CHARACTERIZATION

Data loading has been designed into LYNX based on the typical data which are available and is primarily a process of importing various data types in standard industry accepted formats. Manual input of information through data specific interactive menus, where required, is kept to a minimum.

The data analysis capabilities in LYNX are one of its many strengths. These various analyses functionalities, which lead to a consistent reservoir characterization, are done within the LYNX software. Hence, the results of individual analysis are easily transferred to the simulation model. These capabilities include:

- ◆ Stratigraphic marker review, marker picking, modifying and correlating
- ◆ Summation of well log results at formation and simulation layer levels
- ◆ Facies and cluster determination
- ◆ Inter-shale determination and modeling
- ◆ Determination of reservoir properties at any layering combination
- ◆ Statistical analysis of any parameter for any layer
- ◆ Statistical analysis of any well log parameter
- ◆ Definition of irreducible water saturation from well logs
- ◆ Establishing free water level(s) from well logs
- ◆ Determining reservoir compartments from well logs
- ◆ Establishing capillary pressure functions from well logs
- ◆ Identification of fractures in the wellbore from well logs
- ◆ Quantification of fracture and matrix porosity
- ◆ Distribution of fracture porosity
- ◆ Determination of fracturability from well logs
- ◆ Estimation of fracture connectivity distribution
- ◆ Multi-scale structural curvature (second derivative) analysis
- ◆ Compounding of multi-scale curvature calculations in any direction
- ◆ Comparison of fracture connectivity with well production data
- ◆ Statistical analysis of the reservoir properties
- ◆ Automated variogram generation for sill, correlation distance, and anisotropy
- ◆ Reservoir property mapping through variogram models
- ◆ Object-based sand body modeling
- ◆ Many more

Many of these capabilities are routine analyses required in developing a simulation model. Some are unique functionalities, such as fracture identification and distribution, and reservoir compartment analysis, needed to simulate more complex reservoir systems.

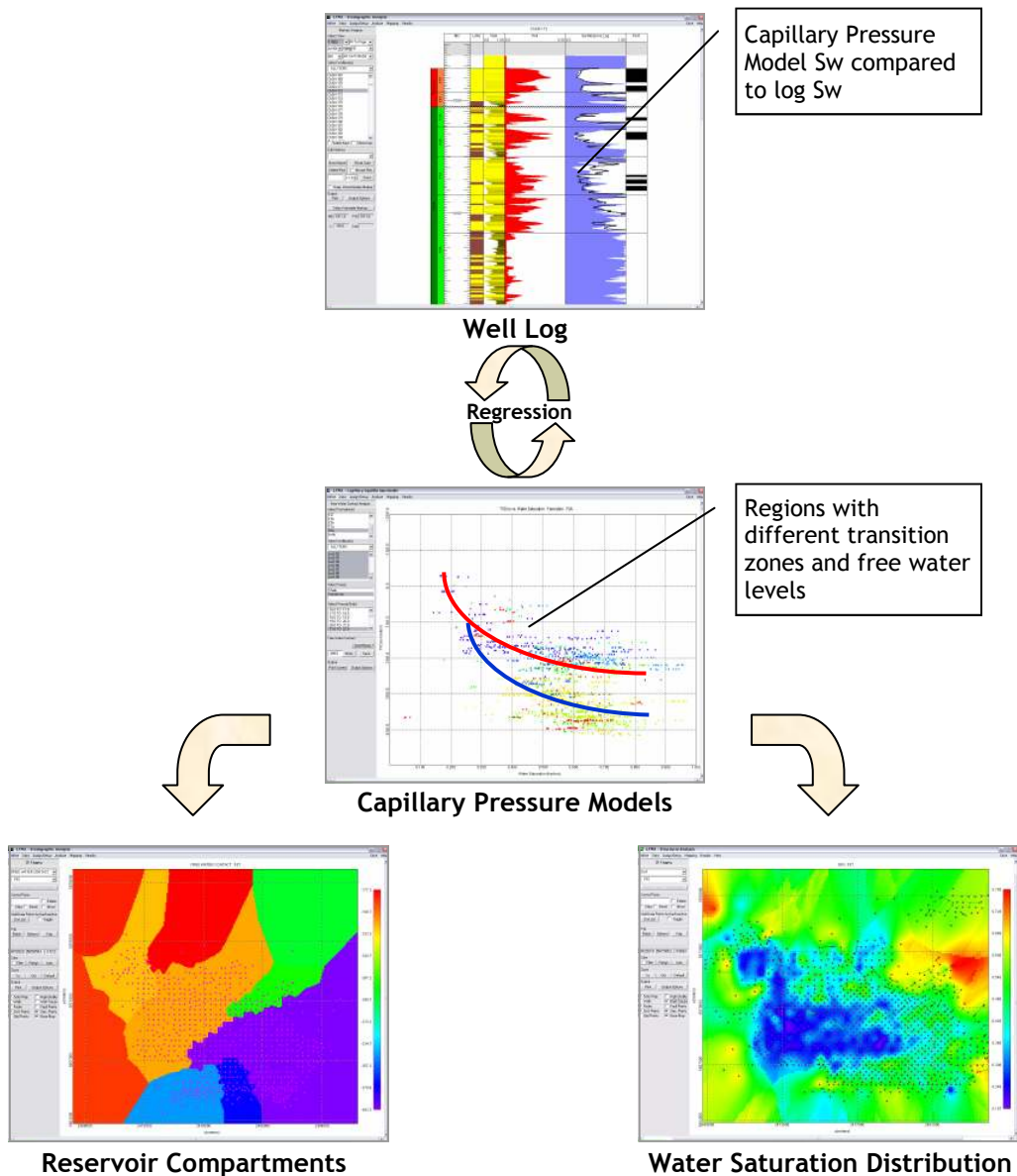
A few of the more unique data analysis capabilities are described in the following pages.

## Capillary Pressure Modeling

LYNX creates capillary pressure models based on lithology, porosity, stratigraphy, free water level, and wettability to match log computed water saturations. During this iterative procedure the user can specify a single parameter to regress on (e.g. bound water, entry height, lambda, FWL) while keeping the remaining parameters constant, or the user can perform multivariate regression on all of the parameters concurrently. Upon establishment of the representative capillary pressure model(s), the saturation function endpoints are populated for each simulation layer. Using a

capillary pressure model that is consistent with log data provides integrity and ensures consistency of the initial fluid distribution in the simulation model.

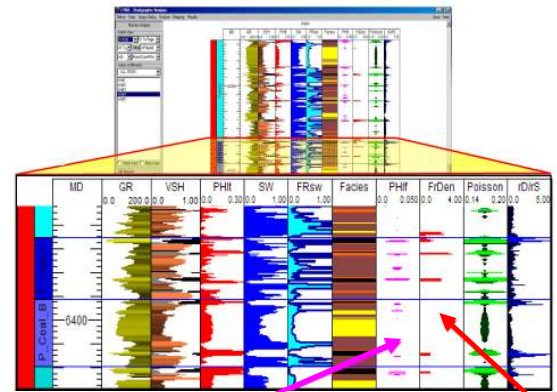
Consistent capillary pressure models also aid in the identification of multiple free water levels and the associated compartmentalization among the reservoir units. This analysis can be conducted at the geologic or simulation layer level. Compartment boundaries can be easily identified and can be associated with faults or changes in lithology.



## Fracture Characterization

Conventional well logs are used to identify fractures in the wellbore. LYNX's capillary pressure modeling approach matches log-based water saturations over the entire interval. The capillary pressure modeling relies on lithology identification, total porosity, wettability, and free water level. Intervals where the capillary pressure model does not agree with the log results are identified as being impacted by fractures and the total porosity is apportioned between the matrix and fractures. Special techniques are utilized in unconventional environments (coals and shales) and facies that may not be associated with a classical free water level. Ideally, the analysis is initially carried out on wells with visual data, such as borehole image logs or core descriptions. The capillary model based fractures are tuned to the visual data. At this point a consistent capillary pressure model exists which is applicable for all wells in the field.

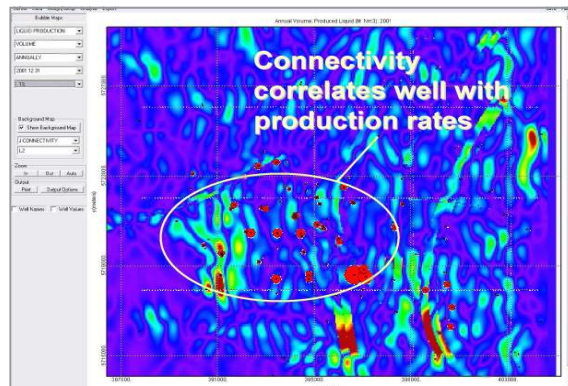
Once the vertical fracture identification is complete, LYNX combines structural curvature analysis with fracturability analysis to define areal connectivity of the fractures. Fracturability is a relative measure of the



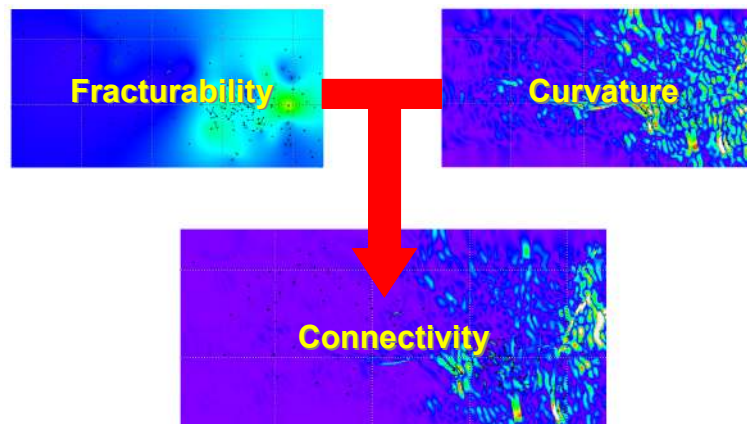
Lynx Fractures Image Log Fractures

likelihood of the rock to fracture and is related to rock hardness (lithology, porosity, and any visual identifiers). Structural curvature is the rate of change of the slope of the structural surface. It reflects the stress history of the formations. The curvature is analyzed over a number of distance ranges to highlight the range of fractures present in the field. Given the current day principal stress directions, fracturability and structural curvature are combined to create a connectivity distribution. Connectivity is a relative measure of the connection of likely fractures. These connectivity distributions can be directly exported along with the matrix and fracture porosity distributions to a dual porosity simulator for each geologic or simulation layer.

Connectivity distributions are converted to fracture permeability values by a single permeability multiplier. Hence, the absolute value of the permeability is determined without the need to change the LYNX determined distribution. The intensity of the connectivity distribution provides the variation in the fracture permeability.



Connectivity Map

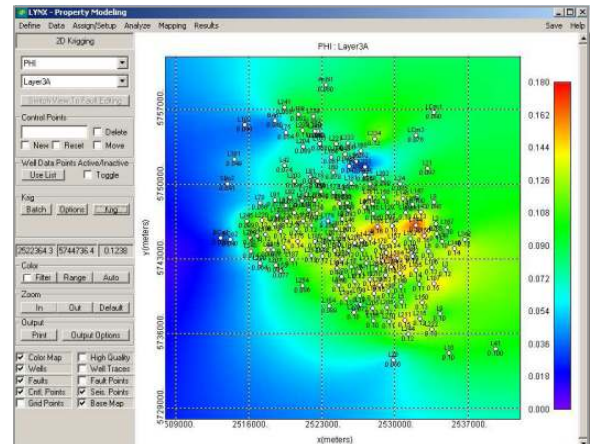


## Variogram Model Generation And Kriging

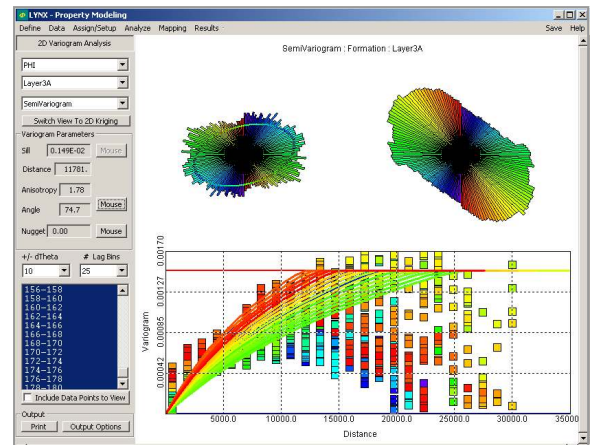
LYNX has multiple options for Ordinary Kriging with variogram models. The standard list of variogram models include spherical, exponential, Gaussian, linear, and cubic. Additionally, LYNX provides a thin-plate variogram model (adopted from spline fitting algorithms) which is useful in identifying areal discontinuities in the data. The solution algorithms for the correlation matrices have been modified to take advantage of improvements in present-day computers.

LYNX has a flexible internal variogram equation which can be used for quick analyses of the data. Upon selection of the property and formation names, multi-variate regression is automatically performed to identify uniform sill and nugget values with corresponding correlation distances for 180 theta bins. The user can select anisotropy direction and ellipse size interactively.

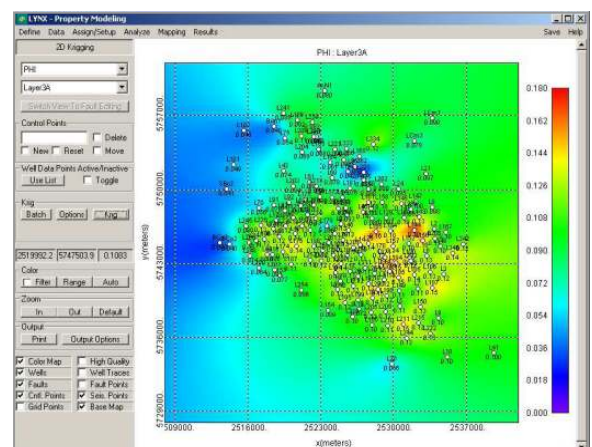
The internal variogram equation in LYNX is robust enough to represent various combinations of standard variogram formulations. The regression calculations have been tuned to progressively modify the weight factors that enable the capture of the shortest correlation distance permissible. The use of this internal variogram equation saves significant time in data analysis and model building. This time-saving feature can be particularly important if the property maps have to be updated during history matching.



Kriging of Porosity with Spherical Variogram Model



Automated Variogram Generation (Nugget=0 Example)



Kriging of Porosity with Automatic Variogram Model

## Modeling of Sand Bodies

LYNX has the capability to analyze facies (sandstone) clusters identified from well logs within a formation to generate vertical proportion curves. Using this information together with various other parameters, LYNX can create stochastic realizations of sand body objects that are constrained by hard data (wells) and other soft data.

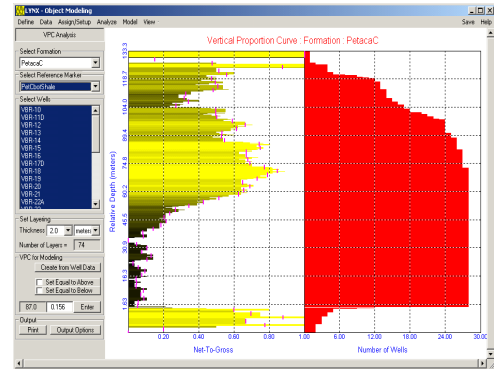
The 3-D object modeling in LYNX is capable of handling variations in shorelines both areally and vertically. The user can specify standard geometric sand channel controls for each event such as width, thickness, sinuosity, and direction through statistical descriptions.

LYNX is especially powerful in the modeling of near-shore depositional environments with the representation of various forces that control the sand deposition mechanism. For each (event) layer, the user can specify one of nine available options that describe the balance of fluvial, tidal, and wave forces that influence the deposition mechanism.

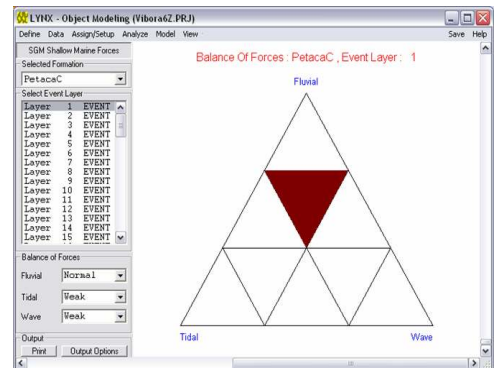
If requested during the stratigraphic correlation analysis, LYNX can convert the present-day facies thickness observations back to original depositional thickness values. This is especially useful when the user is dealing with facies (such as coals and shales) that yield significant compaction upon burial. When this option is used, the 3-D sand object models are generated for the original depositional (uncompacted) conditions and are converted later to present-day compacted condition.

While generating the sand objects, LYNX maintains a color code for each geocellular grid, indicating its relative position to the event top. This information is used to track the tops and bottoms of the channels and can be used in porosity-permeability assignment.

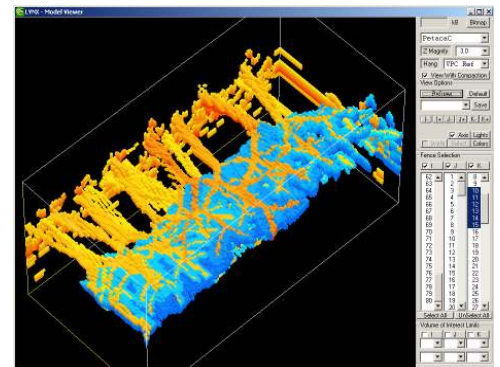
Sand objects are generated such that channel sands can incise into the older depositions.



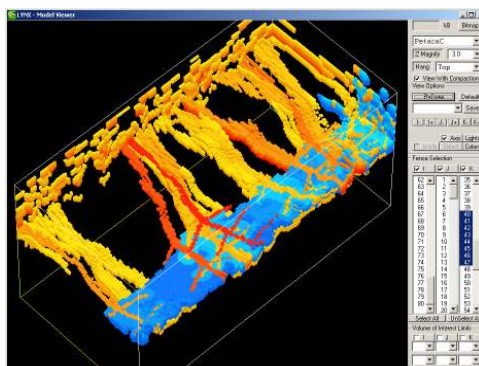
Vertical Proportion Analysis



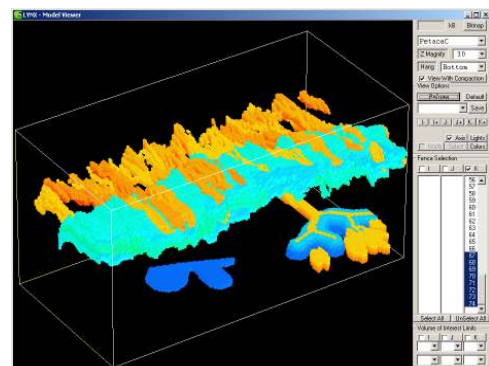
Near Shore Balance of Forces



Balanced Environment (Classic Delta)



Strong Fluvial Forces (Birdfoot Delta)



Strong Wave Forces (Longshore Drift)

## SIMULATION MODEL DEVELOPMENT

Once data analysis and loading has been completed, the data must be transferred and transformed into a reservoir simulation model with a specific grid and layer system. This simulation model will have input requirements unique to the specific simulator being used, as well as data typically required by all simulation software. Currently LYNX model building capabilities are specific to the Eclipse simulator. Other simulators will be addressed as the need arises. LYNX currently can process simulation results from ECLIPSE (Schlumberger), WorkBench (Paradigm), and Sensor (Coats Engineering).

The simulation model construction capabilities in LYNX include:

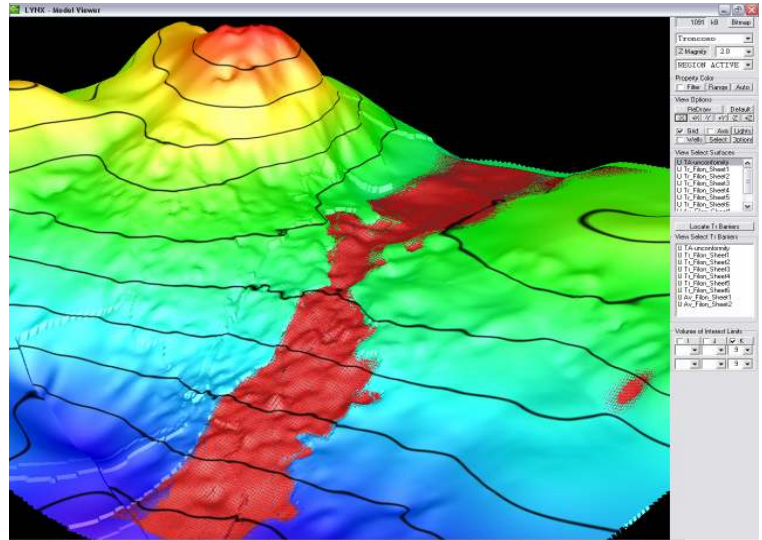
- ◆ Import and mapping of unconformity surfaces
- ◆ Import of 3-D fault surfaces
- ◆ Conversion of 2-D fault traces to 3-D surfaces
- ◆ Simulator grid creation
- ◆ Determination of intersection of unconformity and faults with the simulation grid
- ◆ Calculation and modification of transmissibility values based on unconformity and fault presence
- ◆ Determination of shale thicknesses between formation and simulation layers
- ◆ Calculation of transmissibilities based on shale thicknesses between layers
- ◆ Rules-based activation of transmissibility barriers based on shale thickness
- ◆ Comparison of geologic well markers to simulation grid locations
- ◆ Automatic detection of problems in production and completion data compatibility
- ◆ Automatic location of well string completions from dynamic data
- ◆ Tools to review the rate allocation among the well strings
- ◆ Assignment and modeling of multiple well strings (tubing) into a single wellbore
- ◆ Chronologic assignment of well strings into multiple wellbores
- ◆ Representation of deviated wellbores and multilaterals
- ◆ Automatic location of completions in matrix and/or fracture grid cells
- ◆ Automatic determination of production/injection status
- ◆ Automatic calculation of well down time
- ◆ Rules-based determination of well type (oil, gas, liquid, reservoir)
- ◆ RFT results input for both perforations and entire wellbore
- ◆ Gathering center assignments based on well groups
- ◆ Multi-level well group trees for gathering centers
- ◆ Automatic calculation of gathering center rates
- ◆ Creation of time dependent data for the simulation data set
- ◆ Upgridding of maps to simulation arrays
- ◆ Exporting of simulation arrays
- ◆ Conditional and mathematical functions for array manipulation
- ◆ Statistics and cross plots for arrays
- ◆ Deck building

A few of the more unique simulation model development capabilities are described in the following pages.



## Transmissibility of Intersecting Surfaces

LYNX can calculate the intersection of any surface (unconformity, volcanic intrusions, etc.) with the simulation grid, locate the grid blocks that intersect the surface, determine the direction that the surface intersects through the grid blocks, and create transmissibility traces for the intersecting surface. The user can then specify the magnitude of the transmissibility multiplier that will be applied to the transmissibility traces. The transmissibility multipliers can be different for each intersecting surface.



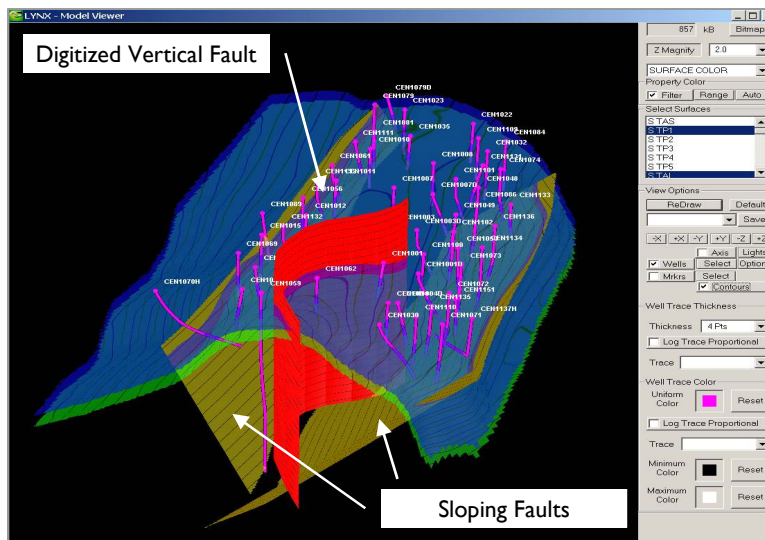
Intersection of Unconformity with Simulation Grid

The same functionality can also be used for faults and regions. Sloping faults can be imported as 3-D fault surfaces and used directly. The 2-D fault traces for vertical faults (or any trace that requires transmissibility modification) can also be imported. LYNX converts the 2-D fault traces to 3-D fault surfaces.

As with the unconformity barriers, transmissibility modifiers for the grid blocks that intersect the fault surfaces can be specified. The magnitude of the modifier can be the same or different for each fault surface.

The fault traces or inferred transmissibility barriers during history matching can also be created (through digitizing) within LYNX and

transmissibility modifiers can be assigned in the same way. In a similar manner, transmissibility modifiers can be specified for the regions to prevent or enhance the flow from one region to another. The transmissibility modifiers can be exported in each direction for all types of barriers or traces (faults, regions, unconformity, etc.) as a single modification file or they can be exported separately for testing different features. This automated procedure eliminates the need for manual modification of transmissibility which is very impractical for fields with complicated barriers.



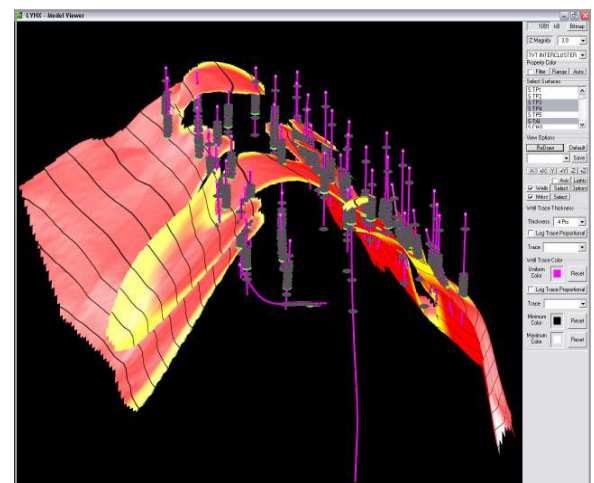
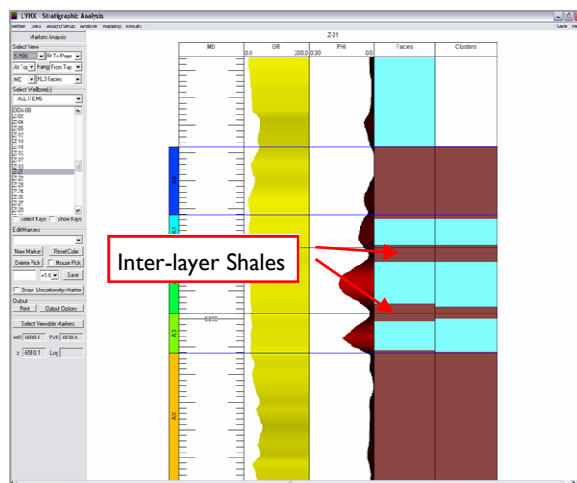
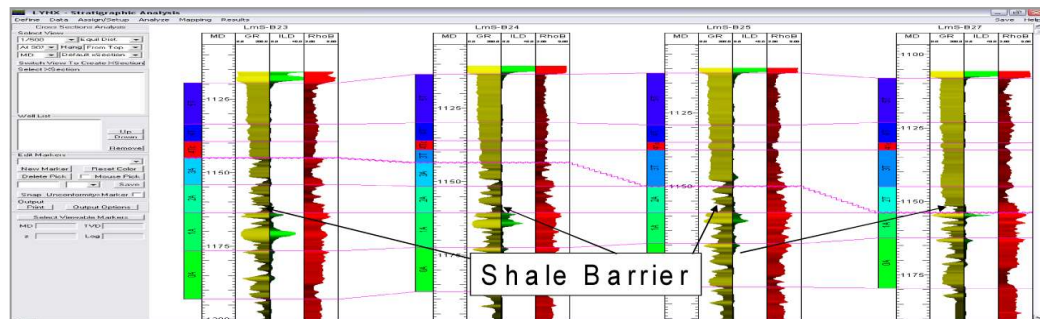
Intersection of Faults with Simulation Grid

## Vertical Transmissibility Shale Barriers

The modeling of the presence of shale among the simulation layers is very important in correctly representing the vertical flow within the reservoir. The effect of vertical communication barriers due to the presence of shales is significant for reservoirs that are undergoing aquifer encroachment, waterflooding, gas injection, tertiary recovery, or even gas cap expansion.

LYNX streamlines the process of determining vertical communication when the shale lenses are present. The presence of shale within the layers impacts the vertical permeability. The thickness of the shale between the layers impacts the layer-to-layer (transmissibility) communication.

LYNX calculates the thickness and the vertical locations of the shale “clusters” through facies analysis of the well logs. The intra-layer shale thickness (the shale present within a layer) is calculated and used in generating the net-to-gross thickness ratio maps. The inter-layer shale thickness (the shale located between two layers) is calculated and mapped for each geological layer. Transmissibility “barriers” are then activated based on user specified rules using the shale thickness values. The inter-layer thickness maps are used to create and populate a transmissibility “barrier” array for each simulation layer.



Shale Barriers Between Layers

# Production and Completion Data Analysis

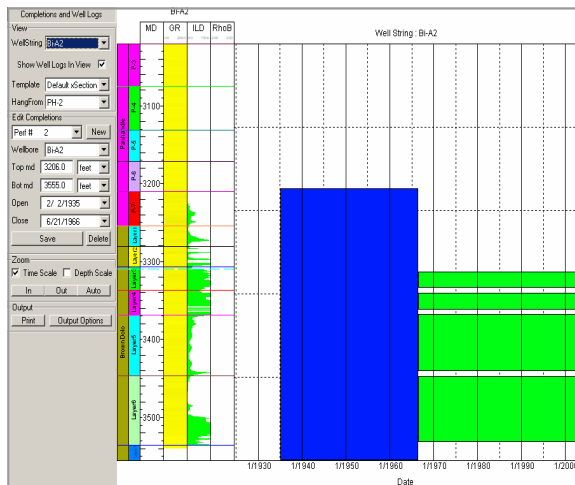
LYNX performs quality and consistency checks on the production and completion data and provides an interface to correct the inconsistencies manually or automatically. Complex completion histories for fields with large numbers of wells are easily handled within LYNX after the data have been imported via a spreadsheet or text format into the LYNX database.

LYNX uses this corrected information together with the simulation grid and well markers to create the time dependent data for the simulation data set.

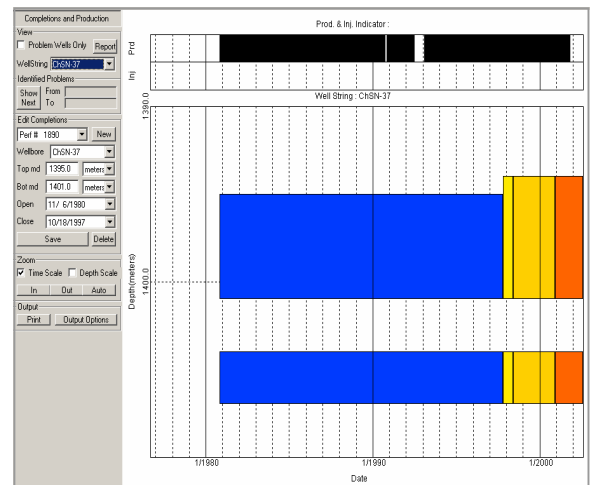
LYNX can perform the consistency check between the production and completion data by scanning through all the production and perforation information and detecting the

inconsistencies (production or injection during period where no completions are defined). This fast and user friendly functionality reports the inconsistencies and displays the production and perforation information graphically for the problem wells so that the nature of the inconsistency can be visually detected.

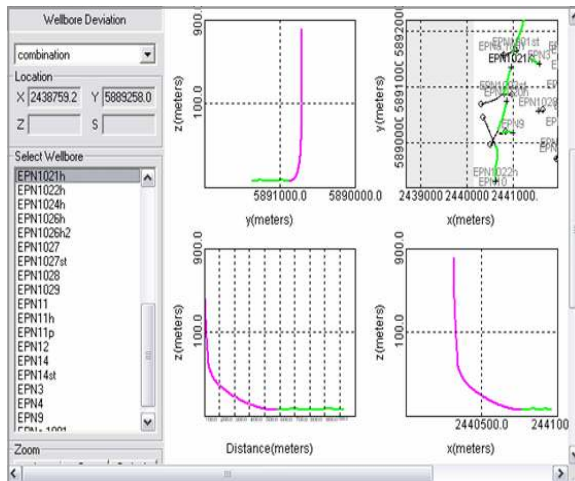
LYNX performs data quality checks on the deviation surveys. This consistency check is carried out before the well completions are located in the simulation grid. The deviation surveys are visualized in all directions and any digitization errors in the data are easily detected and fixed. The trajectory of the deviated wells in the simulation grid can also be visualized to ensure that well completions are located correctly.



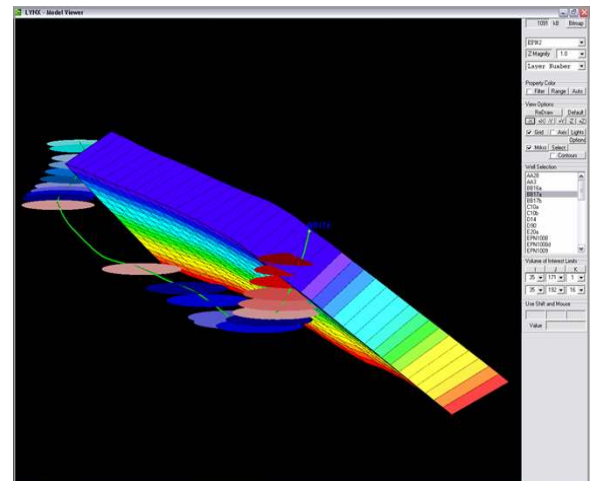
Completion History and Well Log Profile



Completion and Production History



Deviation Survey Schematic



Well Placed in Grid Based on Markers

## Time Dependent Information for Simulation

LYNX creates all the required time dependent information for the simulation model. While doing this it automates many processes and includes the necessary modifications during history matching. This eliminates the need for manual editing. The following paragraphs summarize some of these important features of LYNX.

### Productivity Index Adjustment

The Productivity Index (PI) is a parameter that is occasionally modified during history matching. When different completed zones produce different fluids at different ratios, tuning of the PI may be necessary to adjust how much each zone produces in order to match the total well production history. This tuning is more significant when the well has commingled production from isolated intervals.

LYNX addresses this issue in two ways. First, it automatically calculates a PI multiplier based on the amount of simulation layer penetration. If the completion is fully penetrating the simulation layer, the PI multiplier is not applied; if the well is partially completed in a layer, then the penetration ratio is calculated and the PI is reduced by this factor; horizontal or deviated wells may require a PI multiplier greater than 1.0. Next, LYNX provides an interface where the user can specify PI multipliers for each perforation. The same capability is also available if the PI is multiplied for the entire well without changing the relative distribution of PIs for each layer.

### Automatic Well Type Assignment

LYNX reduces the data set editing time by calculating, assigning, and exporting well and time dependent properties. It can automatically assign well types based on the rules specified by the user. For example the user can set a certain threshold value for water-oil ratio (WOR) and when the historical WOR observed for this well is greater than the specified value, the well becomes a “liquid” well and is constrained by the liquid rate for that time step.

### Completion Relative Permeability

LYNX calculates connection (completion) relative permeability endpoints if requested. It calculates the relative penetration and determines a relative permeability endpoint scaling factor for the concerning connection. If required by the user, LYNX includes the necessary keywords in the simulation data set to turn this feature on.

### Gathering Centers and Well Groups

LYNX assigns the minimum and the maximum limits for the rates and pressures when defined by the user. It has the capability of assigning wells to gathering centers and creating the group tree. It calculates the downtime for each well for each time step and incorporates this information into the simulation data set as well.

### Commingled Wells in Multiple Reservoir Models

LYNX can work with multiple simulation models within the same project. Using model merging or model stacking options, it is possible to create a unified data set where the well perforations can be located in multiple simulation grids concurrently. The dynamic portion of the data set reflects the perforation ordering for the commingled wells accurately.

### Wells in Dual Porosity or Dual Permeability Reservoir Models

LYNX supports the simulation models where the fracture environment is represented as separate layers. Through the detection of the grid block properties, well completions are generated in the matrix and/or fracture simulation layers in the correct order.

## HISTORY MATCHING

LYNX has numerous capabilities to speed the analysis of history match (HM) run results and the creation of the next history match run. LYNX provides this speed and efficiency by automating the data adjustments and processes that are conventionally done manually and by offering analysis tools that aid the simulation engineer in decision making. As LYNX provides an integrated history matching environment, it is always possible to make the changes quickly at the source data level (mapping, capillary pressure model, fracture distribution, etc.) to ensure consistency, accuracy, and integrity of the simulation model. The **MatchingPro** functionality accelerates the HM process through improved understanding of the HM quality (error) relative to individual model parameter changes.

The history matching process is greatly enhanced through these functionalities:

- ◆ Rapid loading of simulation case results
- ◆ Flexible pre-defined and user-defined plots of field, group, and well history match results
- ◆ Grouping of the history match plots based on well type, location, etc.
- ◆ Management and reporting of multiple simulation cases
- ◆ Reporting of observed RFT data and well log saturations against comparable simulation results
- ◆ Reporting of observed PLT measurements against comparable simulation results
- ◆ Mapping of pressure mismatches over specified time periods
- ◆ Mapping of production/injection phase mismatches over specified time periods
- ◆ 3-D visualization of array results
- ◆ Dynamic results animation of array results
- ◆ Visualization of array cross plots and histograms
- ◆ PI multiplication for the individual completions or the entire well
- ◆ Automatic PI calculation based on completion interval
- ◆ Automatic completion relative permeability calculation based on completion interval
- ◆ Fast identification of reservoir compartments (locations and fluid contacts)
- ◆ Rapid modification of transmissibility multipliers for faults and other barriers
- ◆ Easy modification of property arrays
- ◆ HM parameter-HM quality sensitivity analysis
- ◆ HM parameter range guidance based on “mismatch” error criteria
- ◆ Alternative parameter selection for improved HM quality

A few of the more unique history matching capabilities are described in the following pages.

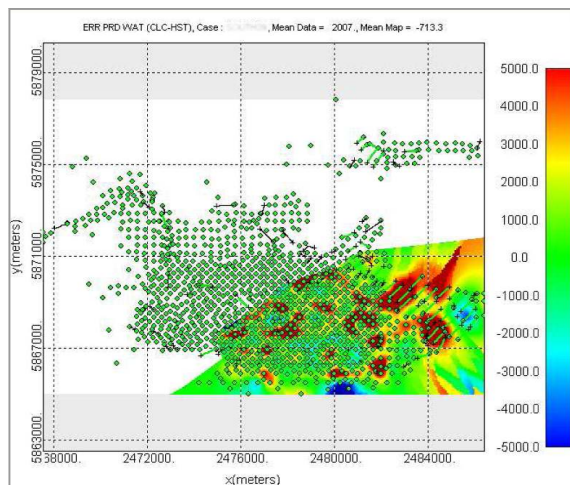
## Identification of HM Mismatch

One key to a successful history match is the proper identification of the ‘mismatches’ between the actual data and the simulation model. The mismatch may increase or decrease with time and is variable from well to well throughout the field, as well as over time.

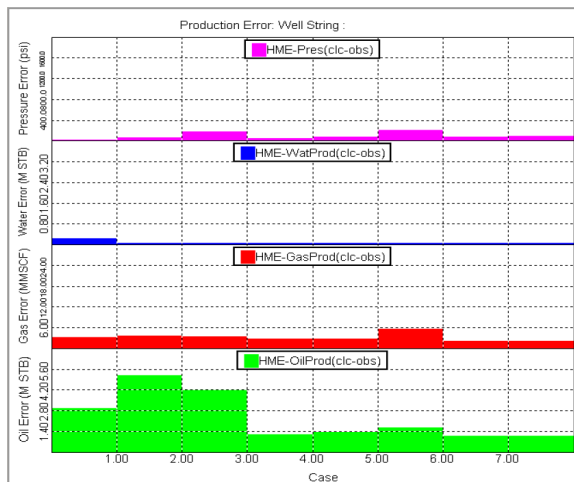
LYNX calculates the difference between the simulation results and the observed data for pressure and the production of all three phases for each time step. It also provides a quantitative measure of the mismatch over time or the cumulative/average mismatch within a period of time. These values can be easily mapped allowing a quick identification of the problem areas in the simulation model.

This focuses the user on determination of regional property modifications for the next history match run.

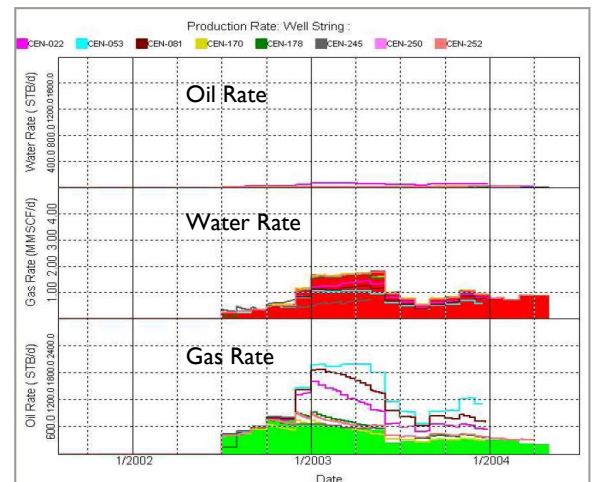
LYNX calculates the difference between the actual data and the simulation model results to evaluate the mismatch in three different ways. L1 is the average mismatch during the specified time period; L2 is the average of the absolute value of the mismatch during the specified time period; L8 is the maximum mismatch during the specified time period. Different mismatch values for different parameters can be displayed for different history match cases to evaluate the HM improvement from case to case.



Monthly Water Production Mismatch Map



L2 Production Mismatches for Multiple HM Cases



Multiple HM Cases

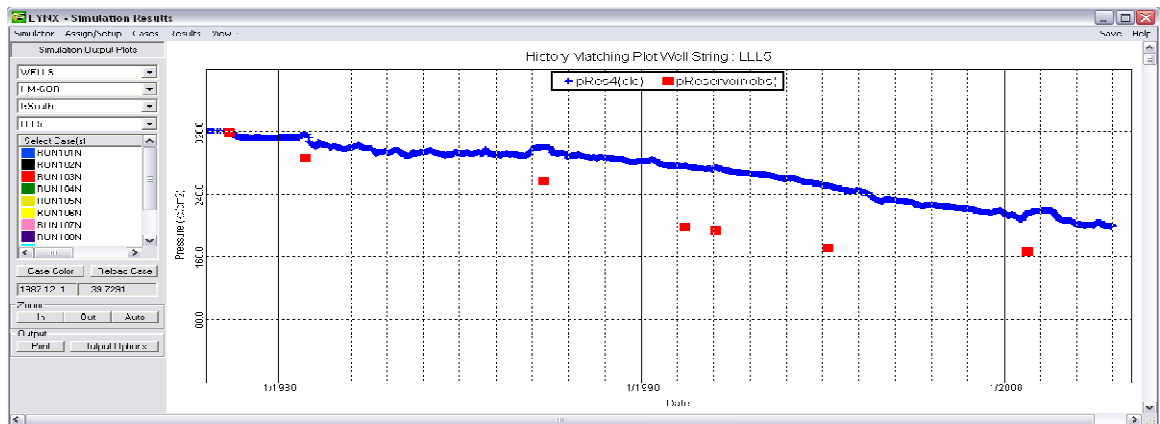
## Pressure Mismatch Identification

The process of matching historical pressure data with the simulation model is a technically challenging task. LYNX speeds the process by providing a number of tools that simplify the simulation results analysis and the “next” step adjustments to improve the history match. All the available pressure data (static pressure, BHP, RFT) can be loaded and analyzed within LYNX. LYNX makes the necessary adjustments to the display of data (i.e. correcting pressure values to the depth of interest) so that they can be comparable with the simulation results.

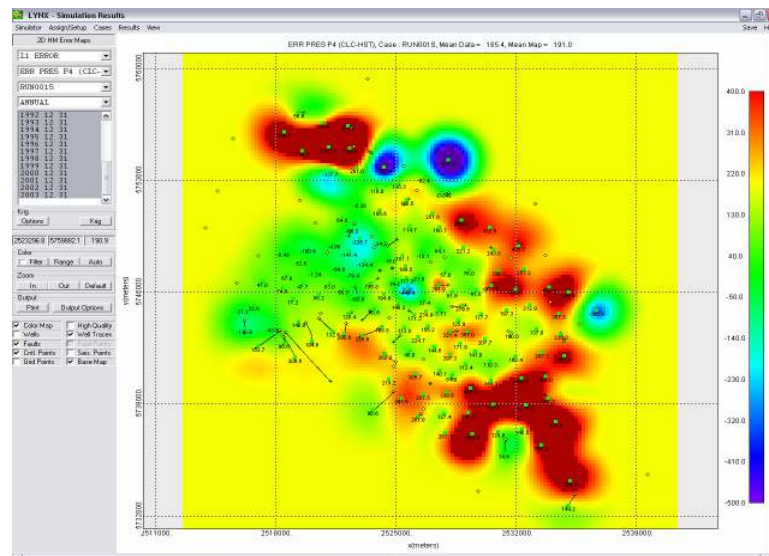
In order to calculate the error in the pressure match, the observed pressure data is compared to the pressure reported by the simulator. A different weight factor (confidence level) can be assigned to each pressure measurement. Depending on the reservoir quality and the

type of pressure measurement, the observed pressure may be compared to P1 (pressure of the cell where the well is located), P4 (average pressure of the 4 cells surrounding the well), P5, or P9. LYNX allows the user to select the simulated pressure to use for the error calculation.

In addition to the conventional pressure versus time history match plots for individual wells, LYNX also provides pressure mismatch maps which allow the user to quickly identify problem areas in the model both areally and over time. This focuses the user on the problem areas and helps to determine the global and regional property modifications (permeability, faults, barriers, etc.) for the next simulation model HM run.



HM Pressure vs. Time Plot



HM Pressure Mismatch Map

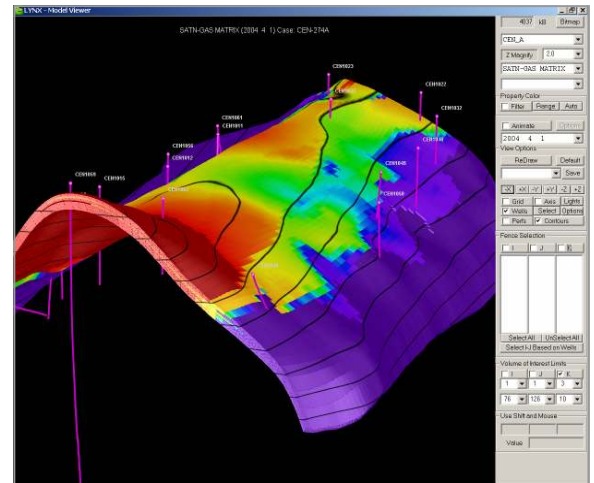
## Visualization of Simulation Results: History Matching Arrays

LYNX displays any initial (porosity, permeability, etc.) or time dependent (saturations, pressures, etc.) array in a 3-D visualization environment. Any property can be displayed with the structural contour lines to enhance visual clarity. Time dependent parameters can be tracked via an array animation facility.

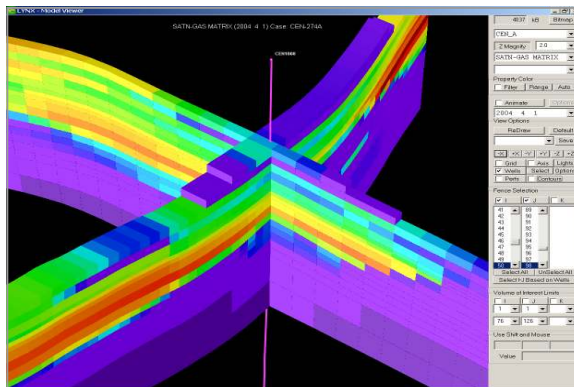
In addition to conventional grid-slicing capabilities, LYNX can create grid fence diagrams based on well locations. Upon selection of a specific well, LYNX automatically creates two cross sections along the I and the J locations of the selected well. This well view can be saved as a template for later use. This feature can also be used to create fence diagrams for multiple wells.

LYNX provides unique array analysis tools like array cross plots and histograms to review the relationships between the arrays and statistics

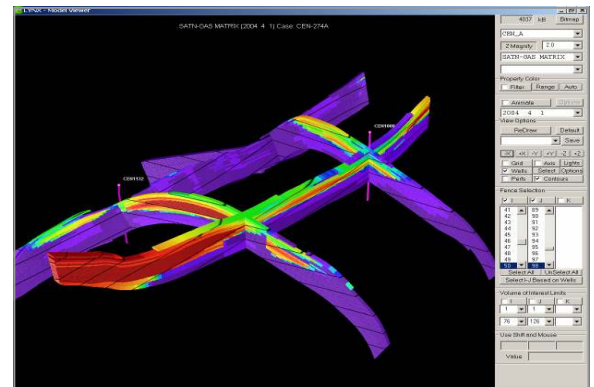
of the grid properties. These tools aid the engineer to perform consistency checks after each modification made during the history matching process.



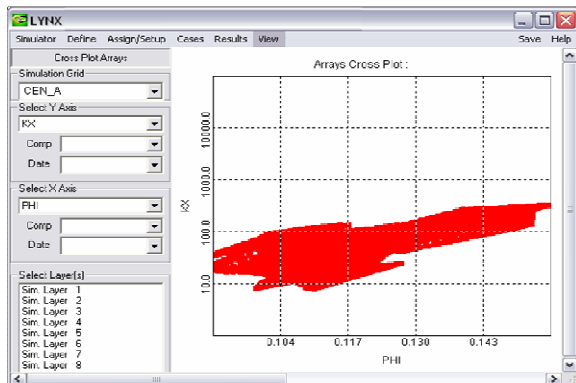
3D View of Saturation at a Specific Time Step



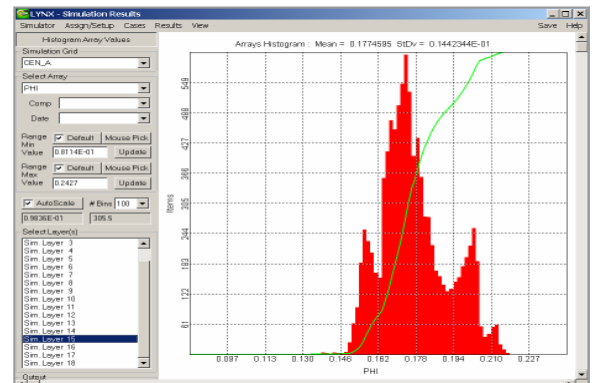
Fence Diagram for Individual Well



Fence Diagram for Selected Wells



Porosity-Permeability Arrays Cross Plot



Histogram of Porosity Array



## Visualization of Simulation Results: History Matching Plots

LYNX can display any number and type of history match plots in any size, stacked vertically. It is very easy to toggle between well, gathering center, and field plots. It is possible to scroll between plots by using the mouse scroll, by keyboard arrows, or by picking the well name from a list. The axes ranges can be modified by a right-click and the templates can be changed by a simple pick. When necessary, a rectangle zooming tool is used to magnify selected data in time scale.

Multiple simulation cases can be displayed and case colors can be customized. The legends and titles of the plots are automatically assigned based on the cases and the data type.

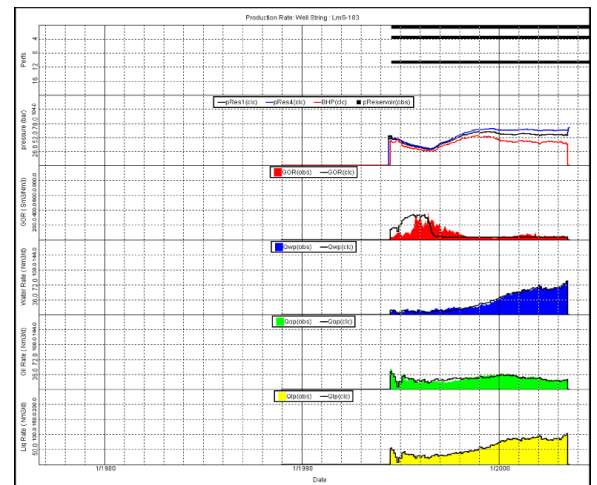
When analyzing the history match results, it is often beneficial to focus on specific groups of wells in the same area. Well groups are easily created within LYNX by outlining the areal location of the wells using a polygon on the well location map. Well groups can also be created by using a well string list.

The well strings in a well group can be categorized by their type (injector/producer), and sub-groups can be created from a well list. When a well group is selected, only the wells in that group are displayed in the well result plots. This functionality facilitates a focused and systematic examination of the results and significantly speeds the analysis time.

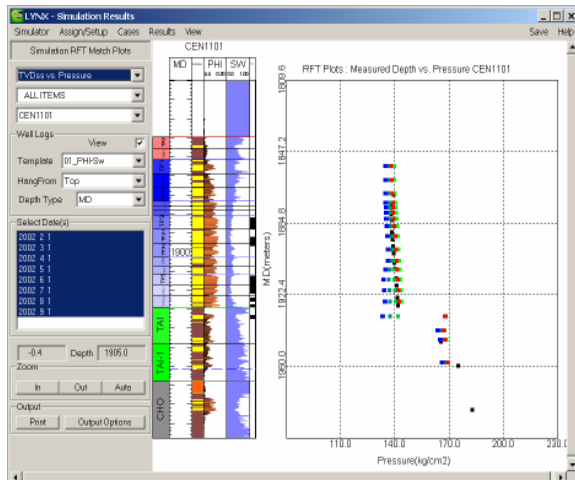
In addition to the conventional history match plots—pressure, rate, etc.—LYNX provides the unique and powerful capability to display RFT

data along with simulation results. It displays the RFT data points together with the RFT output for a selected time period during the simulation in a depth trace for pressure and water saturation. It is also possible to display the well log of the well in order to view the corresponding formation, layer, and perforations. The results of the simulation are displayed over the entire well, not just the perforations.

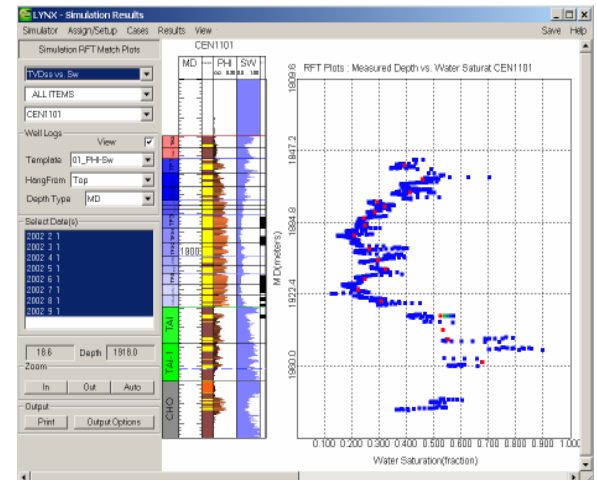
LYNX is capable of converting the RFT pressures to static reservoir pressures which are comparable to the simulation pressures. This feature incorporates more observed data into the HM analysis and helps the engineer to make more informed decisions without reviewing the whole suite of RFT information.



Stacked HM Plots



RFT Pressure Profile vs. HM Results



RFT Sw Profile vs. HM Results

## MatchingPro Functionality

**MatchingPro®** is the latest innovative history matching (HM) technology from NITEC that is very easy to use, fully utilizes available computing resources, and provides fast, reliable HM solutions. **MatchingPro** only requires a reservoir simulation model combined with historical production, injection, and pressure data to accurately and efficiently determine the best HM solution based on the selected HM parameters.

**MatchingPro** can function in auto or manual modes to achieve a high quality HM solution. In the **MatchingPro** auto mode, simulation cases are designed, run, and evaluated without user intervention. The process is expedited by utilizing multiple computer CPUs, when available.

**MatchingPro's** cutting edge technology makes use of Artificial Neural Networks (ANN), Genetic Algorithms (GA), and statistical methods. These algorithms quickly reveal the complex relationships among the HM parameters and the simulation results (the mismatch in simulated versus historical volumes and pressures). **MatchingPro** quantifies the quality of each HM case and recommends the best combination of HM parameters to achieve the best HM solution. **MatchingPro** can also determine multiple HM solutions (model characterizations) and provide a quantification of their probabilities of occurrence.

### The MatchingPro Process: Auto Mode, Single Solution

The observed performance data sets are easily loaded into **MatchingPro**. This includes: individual well monthly production or injection volumes; static reservoir pressures from build-up tests or shut in wells; and dynamic bottom-hole pressures from flowing wells.

The HM parameters and their associated physical ranges are defined via an interactive window. The parameters can be continuous or discrete by defining them as real (linear or logarithmic), or as integer.

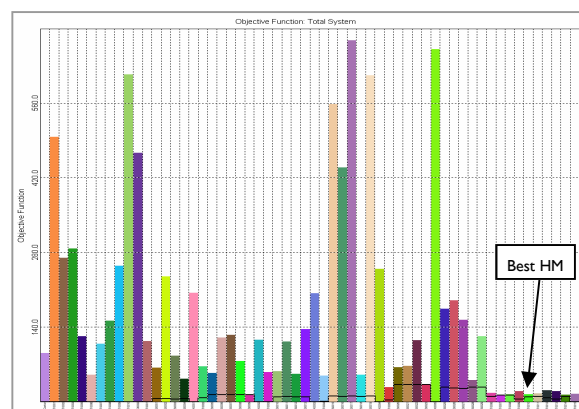
In order to search for the best solution (defined as a set of HM parameters) or multiple solutions, an objective function is defined. The objective function weighs each “mismatch variable” (oil, water, and gas production,

injection, and pressure) for use in the minimization calculations. The mismatch can be minimized for selected wells, gathering centers, or the total field. **MatchingPro** includes a default objective function that is applicable to most situations. The objective function can be modified at any time during the history matching exercise (auto or manual mode) and does not require repeating of the simulation cases or regeneration of the correlation model.

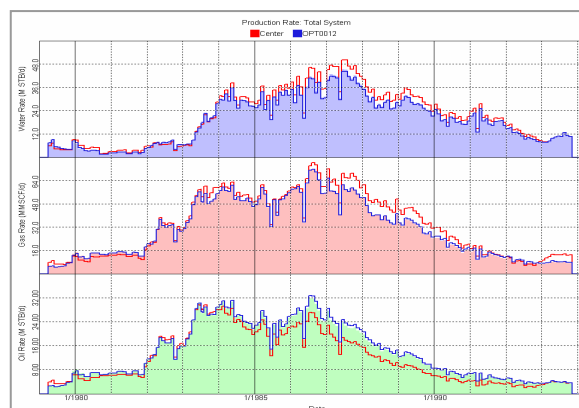
**MatchingPro** commences a pre-determined iterative process. Simulation cases are created, run, analyzed, and displayed as each case is completed until the entire routine is finished. Once all of the runs are executed, the final plot reveals the best HM solution.

Parameter	Real?	Log10?	Min Value	Max Value	Comments	Done
1. APhiFAniso	<input type="checkbox"/>	<input type="checkbox"/>	1.0000000e+000	4.0000000e+000		
2. CurvI	<input type="checkbox"/>	<input type="checkbox"/>	2	10		
3. CurvJ	<input type="checkbox"/>	<input type="checkbox"/>	2	10		
4. KvHm	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	9.9999997e-005	1.0000000e-003		
5. KvHm	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	3.0000001e-004	3.0000000e-003		

History Match Parameters Definition



Completed History Match Cases



First/Best History Match Cases

## MatchingPro Functionality

### Multiple History Match Solutions

One of the unique features of **MatchingPro** is the ability to generate multiple history match solutions for the same HM problem. **MatchingPro** also calculates the probability of occurrence of the set of HM parameters determined for each acceptable HM solution. The minimized objective function value is typically very similar for each solution. However, these different solutions may result in very different performances in the prediction cases. This highlights the well known non-uniqueness of HM solutions.

Once the **MatchingPro** process has completed and a satisfactory history match solution has been found as exhibited by the very low objective function value, the user can utilize **MatchingPro's** solution clustering algorithm to determine multiple HM solutions. These solutions may be equally acceptable from the perspective of the objective function (overall HM error), but will have different values for the individual HM parameters

The user can utilize **MatchingPro's** Monte Carlo technology to sample the correlation model, say one million times. From this sample, the user can request the number of multiple HM solutions desired. **MatchingPro's** clustering technology groups these solutions accordingly and calculates the probability of occurrence for each.

Each of these solutions will have different HM parameter values, but the objective function value will be very similar indicating an equally acceptable solution.

While the HM parameter values appear similar, experience indicates that very minor differences in the final HM parameters can result in significant variations in prediction results.

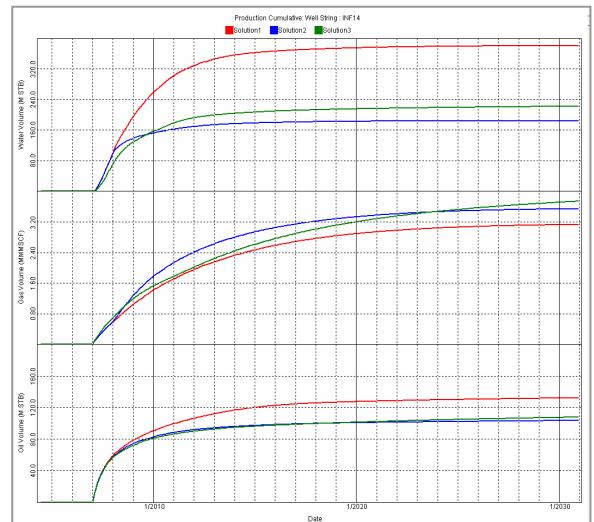
A display of the predicted performance for a well in a large field where three HM solutions were generated shows the predicted performance for the same operating scenario can be quite different for the three cases.

Parameter	Minimum	Minimum Subdomain	Value	Maximum Subdomain	Maximum
1 AQJ	1.00000	1.0000000	6.0104729e-001	1.0000000	1.0000000e+002
2 AQPV	1.00000	1.0000000	2.028147e+008	1.0000000	1.0000000e+012
3 OWC	3.30000	3.3000000	3.5656274e+003	3.7000000	3.7000000e+003
4 PERMMult	1.00000	1.0000000	1.1642952e-001	1.0000000	1.0000000e+001
5 POROMult	2.50000	2.5000000	1.4932405e+000	1.5000000	1.5000000e+000

One of Multiple HM Solutions (42% probability)

	AQJ	AQPV	OWC	PERMMult	POROMult
A1	2.0124128e+000	2.5561206e+011	3.5433201e+003	2.4657424e-001	1.1964288e+000
A2	2.1816943e+000	2.5265550e+011	3.5481157e+003	2.6533189e-001	1.1909019e+000
A3	2.0676370e+000	2.9934466e+011	3.5487073e+003	2.5977680e-001	1.2017276e+000
CLS0001	2.0468192e+000	6.8822342e+011	3.6260952e+003	1.8617412e-001	1.4198650e+000
CLS0002	1.5394729e+000	6.2575161e+010	3.6891411e+003	1.0145210e-001	1.0364323e+000
CLS0003	1.1419632e+001	2.4752310e+011	3.6857454e+003	3.6460683e-001	1.1027839e+000
CLS0004	1.3847901e+000	5.8834280e+010	3.6053367e+003	3.1164932e-001	1.2759347e+000

HM Parameters for Multiple HM Solutions (A1,A2,A3)



Common Prediction for Multiple HM Solutions