EarthVision® 7.5

Environmental Suite

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The EarthVision **Environmental Suite** is an integrated software system used by earth science professionals and academics to visually analyze data, create descriptive models based on that data, and perform visual and numeric derivative analyses. Most applications involve geologic structure and properties that vary in three dimensions within zones defined by the structure modeling. The EarthVision Environmental Suite contains the most complete and fully integrated set of descriptive modeling and mapping capabilities available today in a single software system for use on subsurface environmental projects.

EarthVision Environmental Suite users typically use well log or cone penetrometer information to define geologic and hydrogeologic zones, then create descriptive models of contaminant concentrations in soil and groundwater within the zones. Additionally, soil and rock properties can be modeled, those models visualized, and effective hardcopy displays or animated presentations created. EarthVision can perform volumetric and combinatory analysis (such as 3D risk analysis) and pass summarized data to predictive models (such as flow and transport codes).

EarthVision uses deterministic and stochastic estimation techniques to create its geo-referenced data-based descriptive models. A rich set of visualization capabilities allows simultaneous use of many types of information, providing context to the analysis. Images, sample data, cultural data, interpretations, and analytically derived predictive values can all be put together, viewed in two or three dimensions, and turned into extremely effective displays for communication with other professionals and concerned lay persons.

EarthVision contains graphic analysis technology born of over three decades of research and development at Dynamic Graphics, Inc.® No other system offers organizations doing subsurface environmental analysis the breadth of capability or depth of algorithmic sophistication of EarthVision.

Environmental Suite Functionality

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EarthVision can create geologic, hydrostratigraphic, or combined geologic/hydrostratigraphic models, including three-dimensional property models. Properties can be modeled on a zone by zone or block by block basis.

The models are created by calculating volumes defined by enclosing surfaces. “Major faults” are combined first to partition volumes described as “fault blocks.” Subsequently, “horizon” surfaces are combined to create volumes called “zones.” The names assigned to each type of volume, fault blocks and zones, are oriented toward complex faulted geology, as addressed in the petroleum and minerals industry and on such geologic projects as evaluation of sites for deep storage of nuclear waste. For modeling projects such as these, the EarthVision Petroleum Suite is most appropriate, accepting larger data quantities, creating higher resolution models, and allowing generation of hundreds of fault blocks where data are available to support a high fault density.

The EarthVision Environmental Suite, on the other hand, is focused on projects that usually deal with a smaller areal extent, often with a smaller vertical range, and usually with a modest amount of available data relative to the phenomena being modeled. Typical projects for the Environmental Suite involve the analysis and cleanup of sites with contaminated soil and/or groundwater. For these projects, the capability to partition into fault blocks is usually not used for geologic faults. Rather, these “fault” surfaces are actually used to segregate saturated and unsaturated volumes. The “fault” surfaces represent water tables and aquitards in this case. The zones defined by horizons would typically still represent geologic stratigraphy. With this dual partitioning capability, a water table could, for example, partition three zones into six volumes: zone1 saturated, zone1 unsaturated, zone2 saturated, and so on. The Environmental Suite allows creation of up to four “fault blocks” or, more likely, hydrostratigraphic units.

These capabilities are available primarily in two interfaces—the WorkFlow Manager and the Geologic Structure Builder. These interfaces, along with the additional Earth-Vision capabilities, are described next.

The WorkFlow Manager®

The WorkFlow Manager (WFM) offers a geologically oriented process flow, guiding users through the process of creating 3D faulted and non-faulted structure and/or property models, and various outputs and analyses from those models. Structural models can include overturned surfaces, such as recumbent folds. All the necessary tools for creating 3D models are laid out in a straightforward pattern, so that the user can easily follow the correct path. Specially designed workflows are available for creating time models and velocity models, and then converting from time-to-depth. The new depth model can be automatically adjusted to well picks during the conversion process.

The WorkFlow Manager streamlines model-building procedures for easier use, faster and easier model updating, automatic reuse of valid portions of models during updating, and numerous options to set individual user preferences.

Models of faults, fault blocks (up to 4 blocks, which could distinguish, for example, hydrostratigraphic partitions), faulted and unfaulted stratigraphic and hydrostratigraphic zones, and property models within those zones can be calculated, with various output from these models generated: 2D grid surfaces, color-filled contour maps, geologic cross sections, as well as an output sequence file (that can be used in the Geologic Structure Builder) and a WorkFlow Manager project file. In addition, many timesaving features are available:

- version control allows several different modeling scenarios to be carried out with minimal effort

- automatic fault and horizon gridding
- adjustment data for fault and horizon gridding
- generation of indicator property grids so that 3D grids can be displayed on a zone and/or block basis, for easy model verification
- immediate access to appropriate visualization tools for every output type, even while other files are still being calculated
- progress bars and status lights indicating the completion status of the input parameter settings and computations
- automatic error checking and file verification so that only when input data are changed are output files recalculated

The horizon and property gridding provides fast, high quality, zone top and/or bottom modeling by geometrically reconstructing horizons prior to faulting. The robust fault surface calculation includes automatic dying fault polygon generation and an option to include adjustment data.

Geologic Structure Builder

The Geologic Structure Builder (GSB) module constructs three-dimensional models of complexly layered, faulted and non-faulted areas, based on scattered data, surfaces, and 3D grids. While the capabilities in the Geologic Structure Builder overlap those in the WorkFlow Manager, GSB is used more as a toolkit, while the WorkFlow Manager is task-oriented, setting out the necessary steps for performing a particular task.

Structural horizons that span the fault blocks can be automatically generated from scattered data. Using a 3D modeling technique, the horizon is constructed in an unfaulted, geometrically restored space and then refaulted to create the final surface. User-specified extrapolation controls can be used during the process. In addition, where data are sparse, intermediate surfaces can be calculated based on input data and reference surfaces. All surfaces are automatically intersected and truncated based on user-specified depositional, erosional, and unconformable surface relationships. During horizon modeling, the data can be labeled based on their fault block location to verify that all input horizon data points used in gridding were in the correct fault blocks.

Property modeling can also be performed in the unfaulted, geometrically restored space. Property gridding can be performed on a block-by-block or zone-by-zone basis using conformal or non-conformal 3D ordinary kriging, 3D minimum tension, and/or 3D trend gridding. 3D models of property distributions can be calculated within specific layers in each fault block. The resulting fully integrated model can be plotted as cross sections, contour maps, and isochore maps, or analyzed using 3D visualization techniques. 3D property or seismic grids can be displayed on a property, zone, or fault-block basis against a 3D model or data for easy model and gridding verification.

Modeling

Modeling can be performed in an orthogonal or rotated xy space, in depth, elevation, or time.

Property and/or Horizon Gridding can be performed using a 3D modeling technique that transforms that data into geometrically reconstructed unfaulted space. Using this method for horizon modeling yields a surface more consistent with the input data. Used for property modeling, this method allows properties in different fault blocks, but related based on the pre-faulted stratigraphy, to be modeled together.

2D and 3D Minimum Tension Gridding algorithms calculate a smooth surface that closely fits the input data values using biharmonic-cubic spline techniques. These algorithms are general enough to be useful in a variety of applications, and do not require a complex parameter set or extensive experience to produce a useful model.

2D and 3D Ordinary Kriging, the most common geostatistical estimation methods, are available as gridding alternatives to Minimum Tension methods for both regular and conformal cases. Exploratory data analysis tools, along with a flexible variography capability, are included. Additional varieties of kriging are available in the Geostatistics option; refer to the *Options* section later in this document, or the specifications sheet for the Geostatistics Option.

Conformal Gridding models a 3D property whose spatial distribution is directly related to the shape of a surface, such as porosity measurements from a lithology layer that was produced in a sedimentary environment and subsequently deformed. Conformal gridding produces a significantly more accurate model because the current surface shape and the scattered property data are used together as input to the algorithm.

2D Isopach Gridding fits a smooth surface through input data but provides special recognition of zero input z-values to indicate the absence of the surface. In this algorithm, grid node values are initially calculated using only non-zero input values; then in subsequent iterations, the zero inputs are used to insure a logical location for the zero contour line.

3D Non-detect Property Gridding works in a similar manner to the Isopach Gridding (discussed above), only the non-detect p-value can be user specified.

2D Correction Gridding calculates a difference grid, based on scattered input data and a 2D grid, that can be added to a surface as a correction. Typically, this algorithm is used where the input 2D grid is controlling the shape of the output surface and the input data are controlling the location of the output surface in the z-dimension.

Trend Gridding models the general shape of a 2D or 3D surface rather than its local variations. A polynomial equation fit to the input scattered data is used to calculate the grid node values. 2D trend grids are often subtracted from the corresponding Minimum Tension grid to produce a residual surface that highlights anomalies. 3D trend gridding fits a multivariate polynomial equation to the input scattered data. A 3D trend model represents the general distribution of a property in space rather than its local variations.

Fault Gridding can be performed in the WFM using a combination of minimum tension and trend gridding, an effective combination when input fault data points are scarce.

Time-to-Depth Modules are available via the WFM and GSB interfaces, but independently as well. In one module, an average velocity model must already exist; in the other velocity models can be built from data, grids, or a formula.

Constant and average velocities, instantaneous velocity functions (V_0 + kt), and EarthVision three-dimensional grids can be used to convert GSB or WFM structural and property models (or the input data) from the time domain to the depth domain, preserving the model's internal structural consistency.

Faces File Generation and Merging produces the necessary input file for 3D visualization from 2D and 3D grids. The information that is stored in the faces file, for example the intersections of isosurfaces with slicing planes, is calculated in advance of visualization to increase the speed of all subsequent manipulations during visual analysis. The most complex models can be calculated using the WorkFlow Manager or the Geologic Structure Builder.

Faulting

3D faults—near vertical, normal, reverse, and thrust faults—are defined as surfaces. All fault-surface intersections and fault compartments are constructed according to a user-editable hierarchy automatically created by the WFM and GSB modules. Defining faults as surfaces is critical to maintaining model consistency throughout all horizons in the model. The Environmental Suite allows creation of up to four (fault) blocks within any model.

EarthVision utilizes local faulting as a second means of dealing with discontinuities. Rather than partitioning the volume as the 3D faults do, local faults are surface discontinuities. Lines described as vertical faults used in 2D minimum tension gridding result in vertical offsets of the surface along those lines. Polygons described as non-vertical fault files are used in minimum tension gridding to produce sloping surfaces with sharp slope breaks at the polygon boundaries. In environmental projects these capabilities are very useful in modeling man-made alterations to the original geology and topography, such as cuts, fills, quarries, and simple block structures.

Mapping

Many types of data, such as annotation, polygon, traverse, and image files, can be posted on contour and base maps. Contour maps can have independent contour line and color-filled contouring levels using constant or variable intervals. Contour maps derived from complex 3D models provide easily understood representations of reverse faults, major fault gaps, and erosional and fault-wedge contours. The improved representations of layer juxtaposition in these maps are critical tools in fluid migration and hydrocarbon entrapment analyses. In addition, fault-block maps can be generated from Geologic Structure Builder and WorkFlow Manager models.

The Cross Sections module calculates a vertical or horizontal profile, through a stack of 2D grids or a 3D structural or property model, along a 3D well path, a traverse, or an x-, y-, or z-plane slice. User-chosen pattern types, pattern densities, and colors distinguish the different layers in the cross section. A geologic sequencing technique intersects and truncates the surfaces used in the section according to user-specified surface relationships (unconformable, depositional, or channel erosional). In addition to xy versus z cross sections, cross sections of MD (measured depth) versus z can be calculated. Cross-sections along well paths through 3D models can be displayed on-the-fly. Fence displays can be dynamically rotated, inclined, sliced away, etc. These displays provide insight into multi-layer models by revealing the relationships of surfaces throughout the project area. Interactive 3D fence displays can be generated along traverses or 3D well paths through the project area.

Visualization[1]

2D and 3D scattered data, 2D and 3D grids including 3D seismic grids, fault files, image files, polygon files, well paths, and 3D models can be displayed in 3D space using the 3D Viewer module, with 3D stereo viewing available (extra hardware required). The comprehensive set of interactive visualization techniques found in this module are important tools for data verification, data manipulation, well positioning planning, and comprehending complex relationships between data and models of diverse types.

Additional visual and data analysis techniques in the 3D Viewer allow enhanced well-positioning activities. Some highlights include numerous interactive well positioning and display tools; a 3D cursor to measure the distance, dip, and dip azimuth between two or three points of a geologic model; small, independent, cloned windows of an already displayed model from different viewing perspectives allowing improved visualization and placement of digitized well paths; extensive information (including the fault block, zone, property range, dip, and dip azimuth) about any model location when a 3D cursor is interactively placed; editing data in 3D.

The synchronized viewer feature allows users at remote sites on different platforms to view and manipulate the same model in real time across a TCP/IP connection.

Volumetrics

Volume calculations are available for all types of EarthVision models: layer volumetrics from 2D grids, property volumetrics from 3D grids, and sequence volumetrics volume calculations for properties and/or layers from geologic structure models (generated in the WorkFlow Manager or the Geologic Structure Builder).

Layer volumetrics calculate the volume of layers that are defined using a combination of 2D grids, polygon files acting as lateral delimiters, constant z-levels, and minimum thickness values. Yield factors can be specified as a global constant, by a yield grid, or by constants associated with the volumetric polygons. The resulting volumes are written into a customizable volume report. Layer volumetrics can also be performed on sequence files defining WorkFlow Manager and Geologic Structure Builder models.

Property volume calculations are based on 3D grids or sequence files defining WorkFlow Manager and Geologic Structure Builder models. A variety of tools are provided for defining the specific volume desired, such as a property value range for the subject 3D grid, 2D surfaces to act as vertical delimiters, a polygon file, a property value range in a separate 3D restriction grid, etc. Yield factor(s) can be specified as a global constant, by a yield grid, or by constants associated with the volumetric polygons. The resulting volumes are written into a customizable volume report that can be read by other spreadsheet software. The property volumetrics capability can be used to calculate chemical mass based on stratigraphy, hydrostratigraphy and 2D or 3D distributions of porosity and chemical concentration.

Well Display Tools

EarthVision offers extensive well display capabilities for the display of well locations, paths, stratigraphic pick/drilling log information, geophysical logs, stratigraphic columns, and well bore and text annotation. Templates that specify the data and display characteristics can be used to post user-selected borings in the EarthVision 3D Viewer, and on cross sections, well panels, and contour and base maps.

Graphic Editors

Data, grids, images, plots, and associated files can be manipulated using the EarthVision Graphic Editor. This editor emphasizes interactive object positioning and modification (labels, contour lines, polygon configuration, etc.), plot-montage construction, and map-drafting capabilities including user-definable patterns and symbols. A number of files can be displayed during the editing session to act as reference for modifications. The Graphic Editor can also be used to measure distance or area.

Map Digitizing provides data input from flat media using a digitizer. Prior to the digitizing session, a report is generated to help evaluate the map setup accuracy. Map digitizing is fully integrated with the Graphic Editor; the user can move seamlessly between editing on the screen and at the digitizer.

1. For more detailed information, please see the technical specification sheet for this module.

Interpreted seismic sections, shotpoint/base map data, and cross sections can be digitized and edited using the Graphic Editor. Z-coordinates from cross sections or seismic sections can be merged with x- and y-coordinates from shotpoint maps producing a scattered data file. Where lines cross, mistie and correction values can be calculated to apply to the data.

The Color Table Editor creates custom color files that can be used throughout an EarthVision session wherever color is specified. Color tables can be built manually level-by-level, or using color ramping capabilities.

Formula Processing

The Formula Processor enables the user to develop, store, and evaluate formulas that perform numeric and non-numeric field operations on a variety of file types and operations on 2D and 3D grids. A suite of arithmetic and Boolean operators, functions, and grid operations can be selected from the interface and inserted into single- or multi-line formulas. Formulas can include variables allowing re-evaluation with different input values. Users can create their own customized functions and install them in the Formula Processor interface.

File Management

The file management features of the system locate project files, import files into the system, perform initial management tasks, and provide preliminary analysis of a file before time is invested in more complex analyses. File selection is performed using the same menu throughout the system, which includes tools to add a file header, browse and edit the file contents, plot it in 2D or 3D, examine statistics, and perform exploratory data analysis (discussed next).

Exploratory Data Analysis Tools

The Exploratory Data Analysis (EDA) Tools are used to examine the univariant statistics and bivariant statistics of the z-value (2D) or p-value (3D) of one to two data sets and/or grids. In EDA, data can be examined for duplicate data points, for statistical and distribution properties, and for errors in sampling and data division. The analysis of the data (scattered data, property data, 2D grids, and/or 3D grids) is based on graphical presentations of the information. The graphs available are histograms, probability plots, *p-p* and *q-q* plots, and *h*-scatterplots. The graphs are interactive so that data within the graphs can be queried, subdivided on the basis of class intervals or correlation, and modeled using linear and non-linear functions. The graphs generated by the EDA program can be saved and incorporated into reports or maps (via the Graphic Editor or Base and Contour Maps programs). Links are also provided to the Graphic Editor, Plot Viewer, and 3D Viewer.

Geographic Coordinate Transformation

The Geographic Coordinate Transformation module is used to transform scattered data, vertical faults, polygons, annotation, 2D and 3D grids, and traverse files from one projection system to another. Common projections, such as Universal Transverse Mercator (UTM) and the State Plane Coordinate System, are included. Twelve spheroids, such as Clarke 1866 and Hayford International, are supported, and transformations based on user-defined ellipsoids and equivalent spheres are allowed.

Slope Analysis

The 2D Slope Analysis module calculates 2D slope grids and slope arrow annotation files based on non-faulted and faulted 2D grids. These files provide visual information about the direction and magnitude of the slope of a surface.

Data Import/Export

Import programs automatically reformat data for use in EarthVision, providing integration with data providers and other software systems. Import formats include:

- USGS Digital Elevation Models (DEMs)
- USDMA Digital Terrain Elevation Data (DTEDs)
- AutoCad DXF® data and annotation formats
- ESRI ARC/INFO® coverages (ARC/INFO required)
- LAS well files
- SEG-Y seismic data files[1]

For other data formats, site-specific import programs can be created and installed in the EarthVision interface.

2D and 3D grid import/export programs are provided, including both C- and FORTRAN-callable versions of the underlying subroutines. Programs are also available for creating tar files of all files associated with a GSB or WFM project for easier project management and troubleshooting.

1. Developed based on specific SEG-Y formats. For an additional fee, Dynamic Graphics can make program modifications to import other SEG-Y formats currently not supported.

Structure and property models created using the Geologic Structure Builder or WorkFlow Manager modules can be exported to exchange formats suitable for upscaling/upgridding software. Export formats include:

- Grid™ and Flogrid™ from GeoQuest
- GridGenr™ and GeoLink® from Landmark Graphics
- POSC® industry-standard RESCUE™ models (a model exchange program)

Other commonly used input data types include:

- tab-, comma-, or white-space-delimited free-format and fixed-format 2D and 3D ASCII scattered data
- interpreted horizon data exported from seismic interpretation systems
- EarthVision non-faulted 2D and 3D grids
- EarthVision faulted 2D grids
- EarthVision vertical fault files
- EarthVision annotation files
- EarthVision polygon files (used as non-vertical faults, volume delimiters, etc.)
- SGI RGB, GIF, JPEG, and TIFF pixel image formats

Please see the technical specification sheets for the individual modules for complete information about input data files.

The most commonly produced output data include:

- free- or fixed-format 2D and 3D ASCII scattered data
- EarthVision 3D faulted and unfaulted structural and property models
- EarthVision non-faulted 2D and 3D grids
- EarthVision faulted 2D grids
- 2D/3D gridding statistics
- EarthVision annotation files
- EarthVision layer and property volume reports
- 3D property grids derived from WFM and GSB models (zone, fault block, and property)

- plot files containing base and contour maps, cross sections, fence diagrams, and perspectives (EarthVision vector plot, HPGL2, Encapsulated PostScript®, CGM, and DXF formats)
- screen capture images of 2D or 3D graphics (SGI RGB pixel image, GIF, JPEG, PostScript, TIFF, or XWD formats)
- VRML 1.0 files
- AutoCAD DXF data

Options

Geostatistics

The Geostatistics[1] option incorporates the algorithms from Stanford University's widely-used GSLIB geostatistics software library. Algorithms include simple, ordinary[2], and non-stationary kriging, kriging with an external drift, kriging with a trend (universal kriging), and collocated cokriging; both point and block kriging calculations are available. Graphical data preview and variogram generation capabilities are available to set up and optimize model calculation. In addition to the 2D and 3D models produced, variance models can be calculated that help quantify model accuracy.

Network License Controller

To enable the use of EarthVision across a network, Dynamic Graphics offers a Network License Controller option that permits each licensed software seat to be used on any one of a number of specified, networked CPUs. The computer network can be composed of computers from different hardware vendors.

1. For more detailed information, please see the technical specification sheet for this module.

2. Ordinary Kriging is included in the environmental suite; the other geostatistical methods are available as part of an extra cost option.

Other Information

Program Limits

Project size limits for the Environmental Suite are as follows:

- 50,000 input data points for minimum tension gridding or kriging
- 512 x 512 maximum 2D grid size
- 500,000 3D grid nodes[3]
- up to four fault blocks as defined by the geologic structure fault tree

User Interface

In addition to running EarthVision using the graphical user interface, the underlying computations for most modules can be run from the command line or a script file. Script files can be produced automatically by EarthVision. Using these files can be advantageous when, for example, minor modifications to a previous job are required, input data change frequently, or it is desirable to concatenate a series of computations together into a job stream.

Online Help and Documentation

A complete set of online user documentation and user tutorials, including explanatory graphics, is included. Documentation can be accessed from the EarthVision interface or independently using Adobe® Acrobat Reader™.

Online help is available from each application module describing the application area in general terms and the steps necessary to run the module.

In addition to the WorkFlow Manager, workflow procedures to aid users with typical data formatting, model building, and specific modeling techniques are provided online and viewable with most HTML browsers.

Online manual pages are available via the EarthVision Help menu or at the UNIX prompt to provide help for clients running EarthVision from the command line or using script files.

3. The x-, y-, and z-grid sizes cannot exceed 512 nodes, and the product of the x- and y-grid sizes cannot exceed 50,000 nodes during faces file calculation; grids exceeding these dimensions are automatically resampled.

Computer Platforms

EarthVision runs on workstations or personal computers running the following operating systems:

- SGI™ IRIX®
- Sun™
- Linux®
- Windows® 2000

For further information about hardware and software requirements, please visit www.dgi.com/earthvision/support-edhw.shtml online or request a Suggested Hardware Configuration sheet from your Dynamic Graphics representative.

Hardcopy

A variety of plotters and printers, such as color thermal printers, dye sublimation printers, electrostatic plotters, and ink jet plotters can be used to produce hardcopy from the file types listed in the Output Data section.

Please contact your Dynamic Graphics representative for additional information and a list of currently supported hardcopy devices.

Licensing

EarthVision systems are available as perpetual licenses, as annual leases, or on an as-used rental basis.

EarthVision systems and their options are licensed by the user seat. One seat provides one process executed from the command line, or an unlimited number of processes launched in the same window from a single user's EarthVision GUI (up to the memory capacity of the computer).

Other Services

In addition to software licenses, our EarthVision Solution Projects program provides a data-processing service for our clients. Comprehensive EarthVision training for beginning and advanced users is also available.

For more information on the available EarthVision systems, on EarthVision Solution Project services, or for hardware and third party software requirements, please contact your Dynamic Graphics representative, or visit www.dgi.com.

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