RockWorks Glossary

Last updated 2/15/22

The following terms are defined in the context of how they were used within this Project. Other software and disciplines may have completely different meanings for these terms.

Algorithm: A computer process used to calculate, estimate, or interpolate Node values within a Grid or Solid.

Animation: Video (avi, mp4, wmv), animated GIF, or Google Earth movie.

Anticline: A fold within a surface in which both sides dip away from the axial plane (Figure 1).

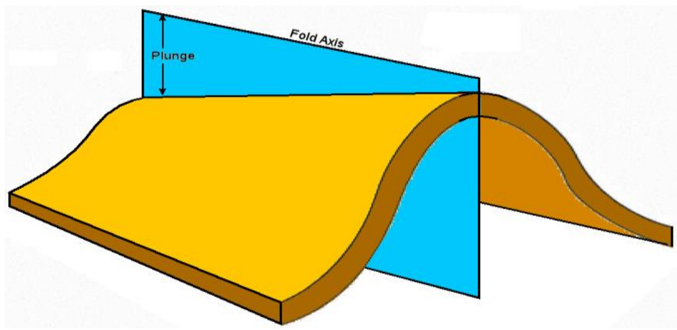

Figure 1. Plunging Anticline

Auto-Kriging: Modeling algorithm that automatically computes the optimal spoke-spacing and tolerance, distance-increment and tolerance, and maximum distance based on point-to-point statistics. A series of eight variograms (exponential, gaussian, linear, and spherical with and without nugget) are then best fit to the observed directional variograms. This algorithm then selects the variogram with the best correlation coefficient (least error) and uses that variogram to krig the data. This kriging process is essentially a form of directionally-weighted averaging.

Bedrock: Materials below the glacial sediments that are considered to be impermeable. Although this term is more typically associated with crystalline rocks, the preferable term of "basement" is not used in order to avoid confusion with the basements below a residence or office building given the local concerns over 1,4-Dioxane contamination migrating into dwellings.

Boolean & Boolean Models: In the context of grids and solids, a "Boolean" model consists of only two possible values: 0.0, meaning "false" and 1.0, meaning "true". If a non-Boolean model (e.g. geochemistry) is multiplied, on a voxel-by-voxel basis with a Boolean model, any geochemistry that corresponds with a false Boolean voxel will be set to zero while any voxel that corresponds with a true Boolean voxel will be left as-is.

Boolean Permeable/Impermeable (BPI) Model: A Boolean solid created by filtering the Permeability model such that all nodes with a value less than less than 0.00002 (2.0×10^{-5}) feet per second were converted to 0.0 (False) while values equal to or greater than 0.00002 were converted to 1.0 (True).

Cell: Element within a grid model. Grids are made up of cells. The value assigned to a cell is referred to as the node value or the Z-value. A cell is analogous to a pixel within a digital image while a grid is analogous to a digital image.

Cell Value: See node value.

Clipping: When used in reference to a grid model, clipping removes cells. When used in reference to a solid model, clipping removes voxels. This removal is accomplished by setting the cell or voxel values to a null value (-1.0e27). The RockWorks software is configured to treat null values as absent rather than zero.

Contamination Plume: Visual representation of a space in water or soil containing pollutants released from a point source of contamination.

Control Point: An observation such as a geochemical sample within a borehole. Grid and Solid Models are created by interpolating cells and voxels between control points.

DEM: Acronym for "Digital Elevation Model". A digital representation of surface topography consisting of regularly-spaced points sampled as a grid model.

G-Value: The value assigned to a voxel.

Grid Cell: See Cell.

Grid Model: Data structure used to model data that has two independent variables (X and Y) and one dependent variable (Z). For any given XY coordinate there can only be one Z value (e.g. elevation). Examples of data that can be modeled with grids include surface topography, surface geochemistry, and formation thicknesses. Grids model XYZ data by assigning an interpolated value to imaginary cells (nodes) within the grid based on the surrounding control points (Figure 2). There are many different gridding methods (algorithms), for performing these estimations, each of which has its own strengths and limitations. There is no universal algorithm that is applicable to all types of geologic data. Also referred to as just "Grid."

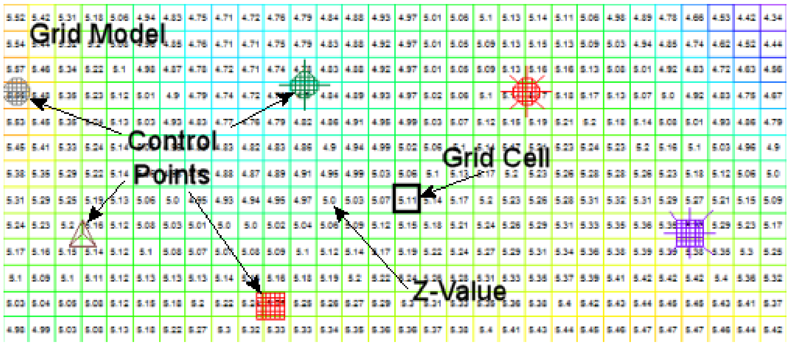

Figure 2. Grid Model Terminology

A Grid Model is not a diagram. Instead it is just a list of numbers that define the XY coordinates and Z-Value for each cell.

Grid Modeling: The process of creating a Grid Model by interpolating the Z-Values (aka nodes or cell values) based on irregularly-spaced control points. Also referred to as "Gridding."

Grid Resampling: A process in which grid nodes are converted to control points and then used to interpolate cell values for a new grid with different cell dimensions. The interpolation is performed by using an inverse-distance weighting algorithm.

Horizontally-Biased Inverse Distance Weighting (HBIDW): This interpolation algorithm is based on a three-dimensional inverse-distance weighting interpolation in which the weighting factor varies with the inclination of a control point relative to the voxel that is being estimated. The influence of a co-planar point will be based on its inverse distance squared whereas a point that is directly above or below the voxel will have an influence based on the inverse distance to a power of five. The weighting factor for all other points will range between 2 and 5 as scaled to their relative inclination. The net result is a modeling algorithm that horizontally biases the influence of the control points.

High-Fidelity (HiFi) Post Processing: A process in which cells or voxels that contain control points are replaced with the control point values in order to honor the data. This process is applied after the initial model has been created, hence the "high-fidelity" nomenclature. If a cell or voxel contains more than one control point, an IDW (Inverse Distance Weighting) algorithm relative to the cell or voxel midpoint is used to estimate the new value. Adjacent cells or voxels that do not contain control points are smoothed to minimize the "bullseye" effect when the new value is significantly different that the original value.

Hydraulic Conductivity: The ease with which a fluid (usually water) can move through pore spaces or fractures. Symbolically represented as "K."

Impermeable: Soil or rock that does not allow a fluid to pass through it.

Inflated Convex Hull (ICH): The shape created by fitting a convex polygon to peripheral control points. This process is analogous to stretching a rubber band around all of the points. The algorithm can also be used to expand (inflate) this perimeter a specified distance outward. Specifying a conservative distance (e.g. ½ Average Minimum Distance Between Control Points) for the inflation will eliminate abrupt and unrealistic terminations against the convex hull (Figure 3).

Figure 3. Inflated Convex Hull

Interpolation: The estimation of an intermediate value into a grid or solid by evaluating the surrounding known values based on an estimation algorithm.

Isosurface: A three-dimensional contour analogous to a skin that conforms to the extent of a given plume concentration (Figure 4).

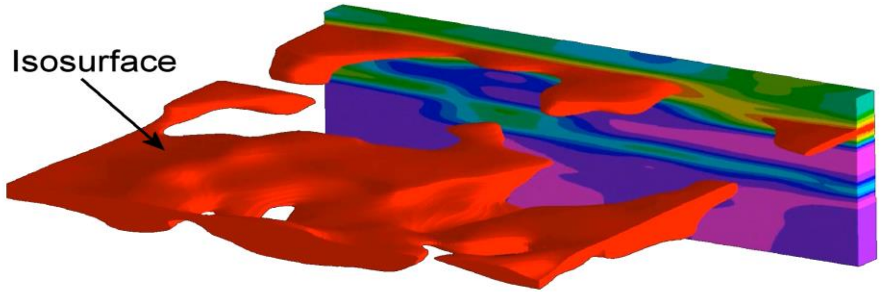

Figure 4. Isosurface

K: Symbolic representation of hydraulic conductivity. Expressed in feet per second.

Lateral Blending: As with Lateral Extrusion, the Lateral Blending algorithm does not attempt to create transitional gradations between the control points. Instead, Lateral Blending will laterally extend observations from each well one-third of the distance to the neighboring wells. The lithology within the center third is randomly selected from the borehole lithologies on either side resulting in a transgressive/regressive appearance similar to hand-drawn sections while still honoring the observed lithologies. The primary difference between Lateral Blending and Lateral Extrusion is that the former method produces more aesthetically pleasing (in a geologically sense) correlations.

Lateral Blending Variability: As previously mentioned, the Lateral Blending algorithm horizontally extrudes the lithologies from the lithologic intervals defined within the wells. This extrusion extends to 1/3rd of the distance to the closest neighboring wells that also have lithology data. The undefined voxels that reside within the center 1/3rd region between the wells are defined by randomly selecting the co-planar lithologies from the surrounding wells.

For example, Figure 5. Simplified Lateral Blending Methodology depicts two wells, named “Well-A” and “Well-B”, separated by a distance of 90 feet. Both of these boreholes encountered alternating lithologies consisting of limestone and rhyolite. The voxels within 30 feet of each well are assigned a lithology based on the corresponding observed lithology within the associated well. The lithologies within the “Random Zone” are determined by randomly selecting a number between zero and 30 to serve as the demarcation point for extending the lithologies on either side.

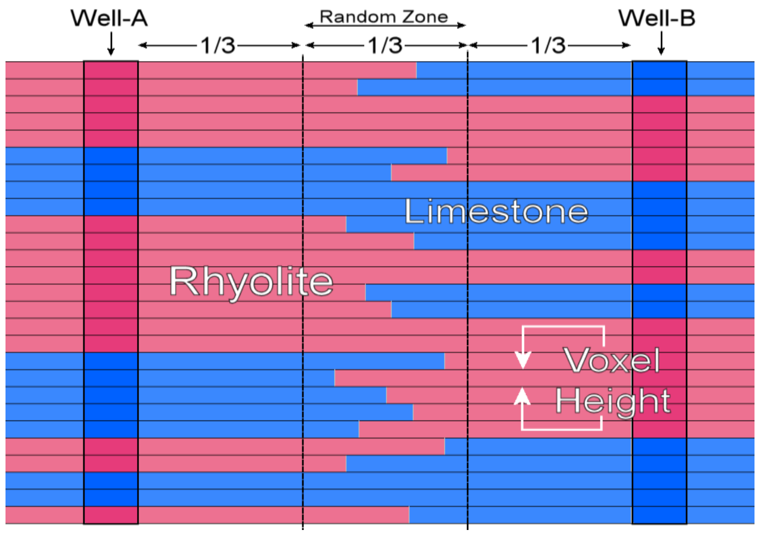

Figure 5. Simplified Lateral Blending Methodology

In order to quantify the variability produced by this process, five lithology models were created for the study area using the Lateral Blending algorithm with the same borehole data. The differences between the models are presented visually within and statistically within .

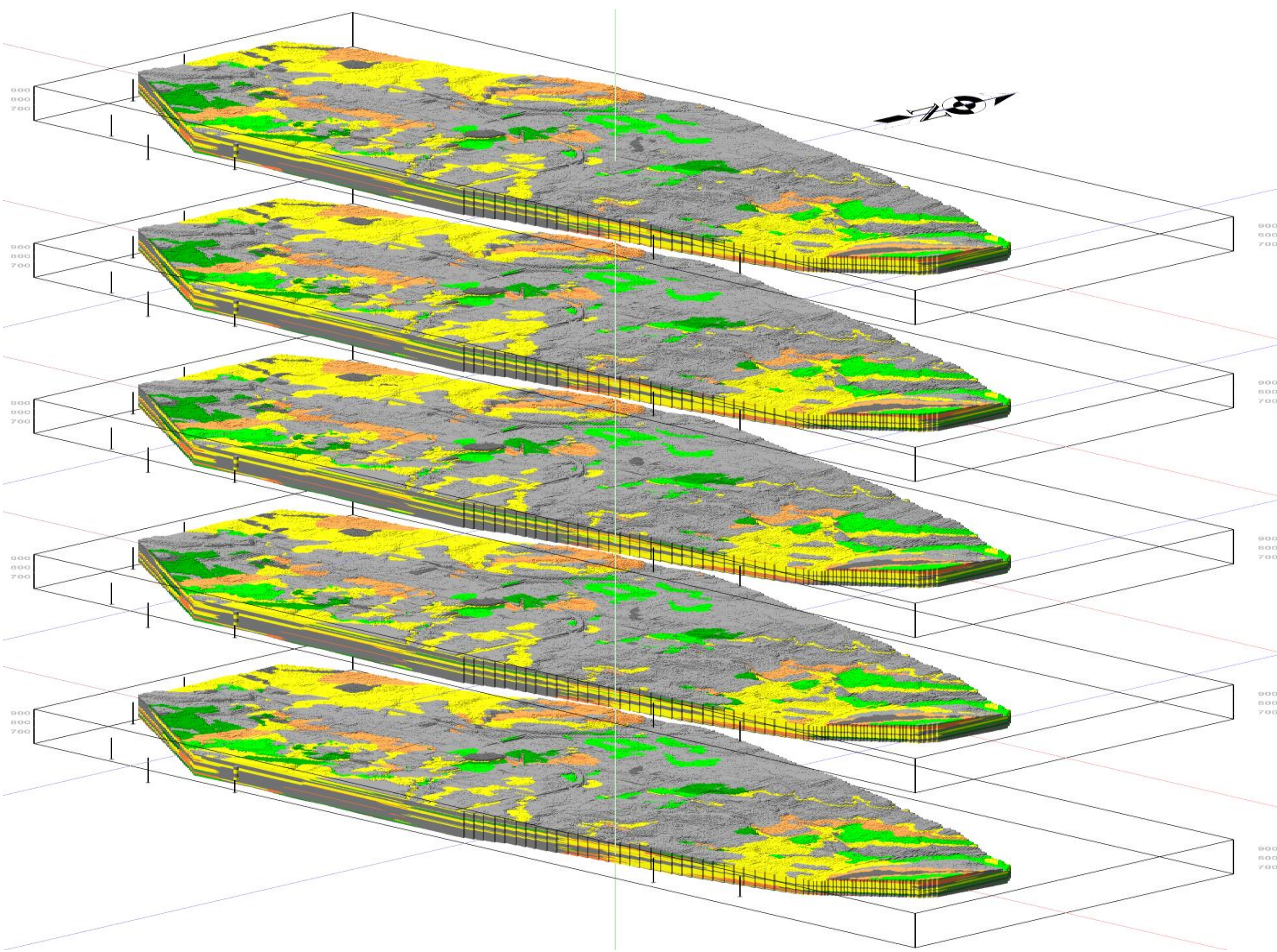

Figure 6. Five Lithology Models Created with Lateral Blending Algorithm

A visual comparison of the models (Figure 6) shows that in areas with dense well control, the differences between the models are too small to detect. Conversely, variations are noticeable within regions with sparse well control.

Table 1. Statistical Comparison of Five Lithology Models Created with Lateral Blending

Lithology	Model (1)					Min	Max	Range	Mean	Standard Deviation
	1	2	3	4	5					
Clay	1234401	1240906	1246566	1242624	1230799	1230799	1246566	15767	1239059	6371.8178
Concrete	243	387	316	66	579	66	579	513	318.2	188.42426
Diamicton	2867570	2860147	2852112	2865581	2868353	2852112	2868353	16241	2862753	6756.1674
Fill	5694	4727	6294	6133	5815	4727	6294	1567	5732.6	611.35121
Gravel	1149554	1145395	1138536	1124936	1148992	1124936	1149554	24618	1141483	10238.626
Inter-bedded	24556	25244	24329	23215	24764	23215	25244	2029	24421.6	754.33766
Peat	5114	5321	5561	5993	4842	4842	5993	1151	5366.2	439.10671
Sand	2103807	2115500	2094355	2114689	2105341	2094355	2115500	21145	2106738	8715.9638
Shale	112373	109964	121547	116864	122038	109964	122038	12074	116557	5385.3787
Silt	175610	180645	181168	173855	170137	170137	181168	11031	176283	4664.0031
Silty Sand / Sandy Silt	388893	379208	397001	393507	385631	379208	397001	17793	388848	6918.4247
Topsoil	8227	8598	8257	8579	8751	8227	8751	524	8482.4	229.60575
Sum	8076042	8076042	8076042	8076042	8076042	Min Range		513		
						Max Range		24618		
						Range of Range		24105		
(1) Number of voxels assigned to lithologies.						Variability		0.2985		

The statistical comparison (Table 1. Statistical Comparison of Five Lithology Models Created with Lateral Blending) indicates that there is a 0.3% variability between the models, meaning that the models can vary by as much as 0.3%. This number was determined by counting the number of voxels for each lithotype and computing the range for the five models. The range of these ranges was then divided by the total number of defined voxels and multiplied by 100 to define the variability.

It should be noted that the variability relates inversely with the voxel dimensions. If the voxels are larger, the variability will increase exponentially. The very low variability (0.3%) associated with the model generated for this report justifies the increased processing time associated with higher resolution models.

Lateral Extrusion: Unlike most of the other estimation algorithms, Lateral Extrusion and Lateral Blending do not attempt to create transitional gradations between the control points. Instead, Lateral Extrusion will laterally extend lithologic observations from each well to the midpoint with the neighboring wells. This creates a discrete model in which the lithotypes do not blend from one type to the other (e.g. rhyolite will not grade into limestone). This algorithm has proven to be well suited for modeling laterally discontinuous units that are too complex for stratigraphic correlations (e.g. glacial deposits west of Ann Arbor, Michigan).

Legacy Data: Data presented within previous reports.

LIDAR: Acronym for "Light Imaging, Detection and Ranging." A surveying method in which a laser is used to measure the distances between the camera and millions of points on the ground. These distances are used to create a digital 3D model of the ground surface.

Lithology: Type of material including concrete, asphalt, soil, sand, gravel, clay, and rocks.

Lithology Model: Solid model in which the numeric voxel values represent the types of material conceptually contained within each voxel.

Lithology Table: Table within the SQL database that defines lithologic terms and their associated patterns, colors, and G-Values. These G-Values define the numbers that are used to represent the associated lithologic terms within the numeric solid models.

Logarithmic/Exponentiating (L/E) Conversion: Before a model is created, all of the control point values are converted to their natural logarithm equivalents. Once the model has been created, the voxel values are converted back to the original range of values by exponentiating the node values. These steps diminish the overwhelming influence of anomalously high and anomalously low values upon the weighting. A useful analogy involves the gravity equation (the basis for this algorithm) which states that gravitational force upon an object varies inversely with the distance squared multiplied by the mass of the object. A neighboring point with tremendous mass (e.g. a star) will overwhelm the weighted averaging thereby rendering the influence of other nearby objects (e.g. a spacecraft) to be insignificant. The logarithm/exponentiating conversion diminishes the mass of the star when computing its influence and effectively allows us to see both the forest and the trees.

Maximum Historical Water Level Surface (MHWLS) Model: An interpolated surface (grid) model based on the maximum water level elevations observed within all of the boreholes for a specified time period.

Mean Sea Level (MSL): Elevation relative to the average global sea level datum.

Model: Either a grid model or a solid model.

Modeling: The process of interpolating node values for a grid model or a solid model.

Node: The midpoint of a cell or voxel.

Node Value: The numeric value assigned to the Node within a grid model or a solid model. When used in regards to a Grid Model, the Node Value is also referred to as the Cell Value or the Z-Value.

Node Spacing: Horizontal or vertical distance between nodes. The Node Spacing essentially determines the resolution of the model. For example, a horizontal Node Spacing of 500 feet means that the model will discriminate features that are 500 feet or greater in width. Conversely, features that are less than 500 feet in width may be completely omitted by the modeling. In a grid, the Node Spacing is the same as the cell width. In a solid, the horizontal node spacing is the same as the voxel width while the vertical node spacing is the same as the voxel height.

Node Value: Number assigned to a cell (Z-value) or a voxel (G-value).

Permeability: The capability of a porous rock or sediment to permit the flow of fluids through its pore spaces.

Pixelation: Blocky, Lego-like, appearance caused by rendering diagrams based on grid or solid models at an enlarged scale.

Potentiometric Surface: In the context of this report, the Potentiometric Surface is defined as an imaginary surface that is based on the maximum water table elevations for all wells from 1986 to 2019. Given the ambiguities with other related terms (e.g. Piezometric, Water Table), this report refers to this surface as the Maximum Historical Water Level Surface (MHWLS).

PPB: Parts per billion (1/1,000,000,000).

Project Area: A geographical parallelopiped (3D rectangle) that is aligned such that the eastern and western borders have an azimuth of zero degrees. The extents (border coordinates) of the Project Area define the dimensions of the models that will be created the RockWorks programs.

RockWare Inc.: Geological software development, resale, and consulting company based in Golden, Colorado. Subcontractor to Mannik Smith Group. Web site: www.rockware.com.

RockWorks: Integrated geological database, analysis, and visualization software developed by RockWare, Inc. Web site: https://www.rockware.com/product/rockworks/

RockWorks Command Language (RCL) Scripts: Batch-processing language that bypass the RockWorks menus and allow for the automated re-generation of all the models and diagrams. RCL Scripts are stored within generic ASCII (American Standard Code for Information Interchange) text files that can be viewed and edited within a simple text editor (e.g. Windows NotePad). RCL scripts consist of blocks of parameters definitions (menu settings) followed by a command that executes the associated sub-program. The example displayed below, shows how a solid model is truncated by an overlying grid model.

```
: Truncate BPI Model Above MHWLS
:--------------------------------
DEFINE: SOLID_G_FILTER_1 INPUT_SOLID      BPI.RwMod
DEFINE: SOLID_G_FILTER_1 INPUT_GRID       MHWLS.RwGrd
```

```
DEFINE: SOLID_G_FILTER_1 OUTPUT_FILE      BPI.RwMod
DEFINE: SOLID_G_FILTER_1 OPERATION        1
DEFINE: SOLID_G_FILTER_1 UPPER_MULTIPLIER 0.0
DEFINE: SOLID_G_FILTER_1 LOWER_MULTIPLIER 1.0
DEFINE: MODEL_DISPLAY    INCLUDE_DIAGRAM  False
EXECUTE: solid_gfilter_1
```

The RCL capability has been replaced by the RockWorks Playlist which was introduced in RockWorks2020. Newer version of RockWorks will still read the old RCL files, but it is recommended that new projects use the Playlist instead.

Solid Model: Data structure used to model data that has three independent variables (X, Y, and Z) and one dependent variable (G). For any given XYZ coordinate there can be only one G value (e.g. 1,4-Dioxane). Examples of data that can be modeled with solids include geochemistry, geophysical data, and ore grades. The three-dimensional cells within a solid are termed "voxels", and just like grid cells, the center of a voxel is called a "node" (Figure 7). Also referred to a "Block Model" or "Solid."

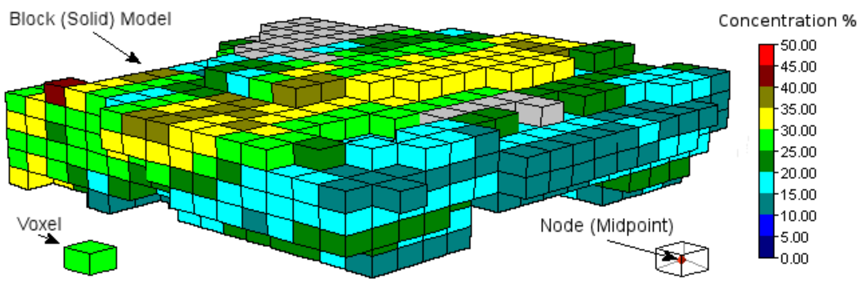

Figure 7. Solid Model Terminology

By way of analogy, a digital picture (essentially a grid), cannot be used to model a deformed onion in three dimensions whereas a 3D radiological CT scan (essentially a solid) can. A digital image is essentially a grid made up of pixels (pixel elements) whereas a 3D CT is a solid, made up of voxels (volumetric elements).

A Solid Model is not a diagram. Instead, it is just a list of numbers that define the XYZ coordinates and G-Value for each Voxel.

Solid Modeling: The process of creating a solid model by interpolating the G-values for voxels based on irregularly-spaced control points. Also referred to as "Block Modeling."

SQLite: Relational Database Management System (RDBMS). Reportedly the most widely used RDBMS in the world.

Trend-Surface Polynomial Algorithm: This method best-fits a polynomial equation to the points. A first-order surface is a plane, a second-order surface has one flexural axis, a third-order surface has two flexural axes, and so on. Second-order trend-surface polynomials have proven to be a very useful tool for modeling potentiometric surfaces because the water levels have reached a state of equilibrium that lacks the crenulations and perturbations that other algorithms, such as Kriging, are designed to enhance.

Vertical Exaggeration: Ratio of vertical scale relative to horizontal scale within cross-sections and 3D diagrams. For example, if the Vertical Exaggeration equals 5x then features are being vertically stretched to five times the horizontal scale. Vertical Exaggeration is used to highlight features that would otherwise be obscured if the vertical scale equals the horizontal scale.

Voxel: Volumetric element within a solid model. Solids are made up of voxels. The value assigned to a Voxel is referred to as the Node Value or the G-Value.

Voxel Value: The value assigned to a voxel. See Node Value.

Z-Value: The value assigned to a cell. See Node Value.