Two-Dimensional Versus Three-Dimensional Geological Resource Modeling – Uranium and Groundwater Resource Evaluation Case Studies

Keywords: Software Modeling Uranium Groundwater 3-Dimensional

Jim Reed jim@rockware.com
Alison Alcott alison@rockware.com

Abstract

From the late 1950's through the 1980's, uranium resources were estimated by picking the tops and bottoms or ore zones from wireline logs. The thicknesses of these zones were then vertically totaled and contoured as "grade thickness maps". A planimeter was then used to compute the area of the individual contours. The resultant area calculations were then multiplied by the thicknesses represented by the planimitered contours and combined to determine the total volume of ore. Finally, the volumetric total was multiplied by the rock density to determine the mass of U_3O_8. These tasks were typically performed manually, without the benefit of a computer.

The aforementioned methodology is no longer suitable thanks to in-situ mining methods that are based on three-dimensional models of the site geology. Instead, the data from the wireline logs (e.g. gamma values) must be digitally stored during the probing process (or digitized from paper logs), geometrically transformed into discrete Cartesian xyzg points, interpolated into block models, filtered by economic parameters, and converted into models that can be used as the basis for in-situ leach-field planning. All of these steps must be performed with computer software.

The same transition in data processing has occurred within groundwater evaluations. In the past, hydrogeologists would pick tops and bottoms for aquifers based on downhole gamma, resistivity, and gamma logs. The thicknesses represented by these intervals would then be used to create isopach maps which were processed in a fashion similar to the previously described uranium evaluation. The volumetric results were then multiplied by transmissivity (permeability) and storativity (porosity) constants en-masse to determine the total amount of available water. Given the practical constraints (time and money), this approach was perfectly reasonable.

Today, aquifers no longer have “tops” and “bottoms”. Instead, aquifer contacts are considered to be gradational boundaries that can only be modeled with computer software. Lateral and vertical spatial variations in transmissivity and storativity are readily handled by three-dimensional modeling algorithms. The net result is more geologically-reasonable resource assessments.

Introduction

Nomenclature

2-Dimensional Versus 3-Dimensional Modeling

Uranium Evaluation – The Classical Method

Uranium Evaluation – The Modern Method

Groundwater Evaluation – The Classical Method

Groundwater Evaluation – The Modern Method

- Create a database of borehole locations (easting, northing, elevation).
    - These locations may be derived from:
        - Log Headers
        - Maps: Requires digitizing.
        - Field Notes
    - The location coordinates may be entered as:
        - Longitude/Latitude: Requires conversion to UTMs or state-plane coordinates.
        - UTMs (Universal Transverse Mercator)
        - State Plane Coordinates
        - Range/Township/Section: Requires conversion to UTMs via commercial “look-up” tables.
    - Ideally, it’s best to work with a Cartesian coordinate system that uses the same units as the borehole elevation and depth information. This eliminates the potential errors later on when computing reserves (e.g. multiplying meters by feet).
    - Create borehole location maps from database and cross-check against historical paper maps.
    - If the elevation information is absent from the aforementioned datasets, it will be necessary to either:
        - Overlay the borehole location maps over topographic maps and manually determine the elevations.
        - Use a DEM (Digital Elevation Model) to determine the borehole elevations.
- Enter downhole geophysical data.

- There are two, very different approaches to the geophysical data entry.
  - Two-Dimensional (classical/fast approach):
    - Pick ore zones from paper logs.
    - Convert gamma counts to ore-grades (e.g. %U3O8).
    - Multiply average grades by interval thicknesses.
    - Enter results into borehole database for subsequent grade/thickness map generation.
    - Advantages:
      - Fast and easy.
      - Inexpensive.
    - Disadvantages:
      - No ability for true, three-dimensional analysis or visualization.
      - No ability to re-model the data based on new ore-grade cutoff levels.
  - Three-Dimensional (modern/slow approach):
    - Digitize logs. This is a slow and tedious process whereby curves (e.g. gamma, resistivity, spontaneous potential) are traced in one of two ways:
      - Digitizing Tablet: Paper logs are taped onto a special surface and traced with an electronic stylus.
      - On-Screen Digitizer: Paper logs are scanned and displayed on-screen. Operator traces curves by moving mouse.
    - The digitized data is then stored within the borehole database as quantitative information (e.g. depths and gamma counts).
    - Advantages:
      - Provides for true, three-dimensional analysis and visualization.
      - Ore-grade cutoff levels may be varied during subsequent modeling.
      - Subsequent analyses (e.g. stripping ratios, ISL (in-situ leach) modeling, etc.) are readily performed.
    - Disadvantages:
      - Time-consuming and tedious.
      - Expensive.
- Enter downhole lithology data (if available) into the borehole database.
- Enter water-levels and sampling dates (if available) into the borehole database.
- Create surface-elevation model based on borehole elevations or DEM (Digital Elevation Model) – if available.
- Create ore-models:

    - Two-Dimensional (Grid Model): If the downhole geophysical data not been digitized (i.e. limited to grade-thickness intervals), these models will be displayed as grade-thickness contour maps.
        - Compute volumetrics (geologic reserves) based on grade-thickness contour maps.
    - Three-Dimensional (Solid Model): If the downhole geophysical data has been digitized:
        - Create continuous gamma block model.
        - Convert gamma block models to %U3O8 model.
        - If downhole lithology data is available:
            - Create lithology model.
            - Use lithology model to constrain gamma values to appropriate lithologic intervals.
        - Filter %U3O8 block model based on economic cutoff level (e.g. minimum acceptable %U3O8) to determine geologic reserves.
        - Create cross-sections, fence diagrams, and three-dimensional diagrams to cross-check the geological viability of the modeling and determine
- The next step is determined by the desired extraction method:
    - Open Pit:
        - Process solid model within pit-optimization software to determine optimum pit design based on pre-defined cutoff levels (e.g. minimum grade, maximum stripping ratio, maximum bench height, etc.)
        - Manually add ramps to computer-generated pit design.
    - Underground:
        - Superimpose mine workings plan (if three-dimensional model is available).
    - ISL (In-Situ Leach):
        - Create resistivity and SP models based on downhole geophysical data.
        - Convert resistivity, SP, and lithology models to porosity/storativity and permeability/transmissivity models. This is a “black art” that adds significant cost.
        - Design an injection/recovery well field.

A quick evaluation of uranium/vanadium properties based on historical data should use the simple (classical) grade-thickness approach. By comparison, the block-model approach is simply too time consuming due to the requirement for quantitative downhole data (e.g. depths and gamma counts at regular intervals).

The uranium should be evaluated as follows:

- One or more test holes are drilled within the deposit.

- The test-hole samples (preferably core) are then sent to one or more reputable, third-party analytical laboratories (e.g. Hazen Research).
- The analytical results from the testing laboratories are then used to establish the conversion factor(s) for converting observed gamma counts to %U3O8.
    - Note: If there's a "non-linear" relationship between gamma counts and %U308 it may be necessary to use an equation rather than a constant for performing the conversion.
- A statistically valid and geologically representative subset of the existing boreholes is then selected for subsequent processing.
- Ore-zones are then manually "picked" from paper logs. These picks are based on;
    - the gamma-to-%U308 conversion,
    - pre-defined grade-cutoff levels, and
    - pre-defined minimum-thickness levels.
- The picks (depth-to-top, depth-to-base, and average grade) are then entered into a spreadsheet.
- The spreadsheet data is then converted, via a gridding algorithm, into an interpolated grade-thickness grid model.
- The grade-thickness grid model is then contoured to make sure that it agrees with the historical grade-thickness maps.
- The grade-thickness grid model is then converted into a volumetric calculation to make sure that it compares favorably with the volumetrics that are claimed by the seller.
- Once the volumetrics exceed the minimum acceptable total pounds, it is recommended that subsequent evaluation be terminated and the properties purchased from the seller. Additional processing via this method is a waste of time and money. Instead, the data should be re-processed via the slower block modeling approach to facilitate the actual mining process. In other words, use the classical grade-thickness approach for an evaluation but switch to block-modeling for the actual mining.

The evaluation of the vanadium should be handled in a completely different (and faster) manner.

- It is assumed that the vanadium data is already available in some sort of ledger format (e.g. depth-to-top, depth-to-base, vanadium grade).
- This data may be entered into a spreadsheet and quickly converted into a block model for subsequent display and volumetric computations.
- This data does not need to be reprocessed once a decision has been made to purchase the property.