Uranium Resource Estimation - Best Practice
Opinions on 2D Versus 3D Resource Estimation specific to Sandstone-hosted Uranium Deposits

2D Polygonal Estimation Limitations (Not a Recommended Method)

There were during the 1960's-1970's, and still are, several methods used to determine local grades and average deposit grades using a two-dimensional (2D) GT (Grade-Thickness product) boundary, the so called ***"GT contour Method"***. The most common of these methods is to create polygons around each drill hole that penetrates the mineralized horizon internal to a GT boundary on plan maps; the GT value selected as a minimum cutoff of potential economic viability for ISR extraction. Polygons are then assigned the average grade of the drillhole. Polygons are created by various methods, such as equal area polygons, using the perpendicular bisector between holes, or by other methods such as Voronoi polygons. Drillhole GTs are applied to each polygon area defined within the GT contours. The area within the GT boundary allows for calculation of tonnage and therefore total contained pounds of eU_3O_8.

Recognized limitations of 2D arithmetic methods include:

- **Estimation at a point** – For polygons, grade estimation is "at a sample point"; whereas, it is generally accepted for all other metals, and also uranium outside the western US, the goal is to estimate grade "between sample points". Since polygonal grades are assigned versus estimated, variances cannot be assessed. This is not acceptable by international reporting standards. The requirements of international reporting standards (JORC, SAMREC, CIM, and CRIRSCO) discuss continuity of geology and grade in terms of correlation between drillholes, not around an individual drillhole;
- **Statistics and Geo-statistics** – Classical statistics to examine grade distributions are rarely used and geo statistics are not applied. Grade populations, grade capping, outlier analysis, and variography should be part of the exploratory data analysis (EDA);
- **Uniform estimation for entire units** – With general outline GT contouring, only a single grade is computed for a given mineralized horizon; the variation of grades within a unit are not identified, other than at each drillhole intercept. This is inadequate for mine planning purposes;
- **Inadequacy of Geologic Modeling** – For both the polygonal and GT outline methods, typically there is no incorporation of three-dimensional representation of controlling geology or important geologic factors (such as faults or variability in groundwater transmissivity) which might have influence on the continuity of mineralization. or have impacts on mining (i.e. recovery). This is inadequate to achieve Indicated and Measured Mineral resource classifications by international reporting standards and is inadequate for mine planning purposes.
- **Inability to carry out Sensitivity/Comparative Analysis** – While the global resources estimated might be realistic as an Inferred resource, the sensitivity of the estimate to various factors are difficult to assess, and reiterative estimations with different assumptions can be extremely cumbersome. This is not acceptable by international reporting standards.
- **Simplistic Confidence Classification** – Classification is only based on average drillhole spacing.
- **Inadequacy for mine planning** – The estimation is unrelated to any conceptual "*selective mining unit*" (SMU), whether mining is by ISR , open pit or underground; and without some conversion into a block matrix representation appropriate for the SMU, mining optimization exercises are impossible. Measured and Indicated Mineral Resources assume potential mineability; therefore, the resource must be adequate for mine planning purposes. A global Inferred Mineral Resource by 2D polygonal/GT contouring methods is inadequate for mine planning purposes.

These limitations of 2D arithmetic methods were recognized in the early 1970's, and were replaced by 3D block modeling including the application of geostatistical concepts, which has been the norm for resource estimation since then. **A 2D polygonal resource estimate for sandstone-hosted uranium mineralization, whether tabular deposits, roll-fronts, or stacked roll-fronts, should not proceed beyond the Inferred classification.**

3D Block Model Representations (Recommended)

1. Recommended Digital Database

At a minimum, it is recommended to construct a digital (Excel, Access, or ASCII format spreadsheet) database of drillhole eU_3O_8% information derived from gamma log data (or assay or PFN U_3O_8 data), to allow for resource estimation to proceed on sandstone-hosted uranium deposits. The database should include:

- x-y-z collar elevations;
- down-hole drift survey information where available;
- down-hole from/to interval eU_3O_8% assay data on 0.5 or 1.0 ft. intervals; averaged intercept thicknesses and grades are not appropriate;
- disequilibrium information, if not already incorporated into the eU_3O_8 database;
- down-hole from/to lithological data; formation name or sand unit designation. Geological control information is necessary, for at least some of the drillholes, in order to determine hole-to-hole correlations of mineralization; and
- down-hole data that may affect ISR well-field recovery such as hydrological data, and chemical assays of associated or deleterious elements.

The recommended data will allow for independent 3D modeling. The data will also allow for third party audits and can be used to audit 2D polygonal historical models. Without a digital drillhole database sufficient for 3D modeling, a 2D resource estimate derived from paper logs and mineralization intercept tabulations is inadequate.

2. 3D Block Modeling

The question must be asked, if three-dimensional (3D) block models are adequate and the current industry norm for most commodities, why not for uranium deposits? It is not an adequate answer to simply state that 2D polygonal methods were acceptable historically, and therefore should be acceptable today as well. **There is no justification for not using modern industry methods of 3D block modeling and geo-statistics for resource estimation of sandstone-hosted uranium deposits.** If the argument is that extreme variations in grade is the justification for "polygonal" estimation, this can be emulated with a nearest neighbor assignment in a 3D block model estimation, and there are other advantages; alternative estimations (inverse distance weighting or Kriging) for comparative purposes and sensitivity analysis.

GT contouring in many cases provides a valid representation of the lateral extent of mineralization and this representation can also be incorporated into a 3D block model representation where the global resource may be comparable to that achieved arithmetically but the variation of grade within the contours is also represented via grade estimation of individual blocks.

Current 3D visualization and modeling software can define mineralization volumes and lithology controls by implicit modeling from the digital drillhole database, which is the necessary first step to resource estimation. A geological model demonstrating geological continuity and stratigraphic/structural controls is required prior to determining mineral resource estimation. The 3D geological model provides proper constraints to the Mineral Resource model of tonnage and grade, and aids in effective mine planning.

3D Block Models have the following advantages:

- Application of basic statistics, geo-statistics, and standard 3D block model construction, followed by linear or non-linear grade estimation (interpolation) techniques will create a block model populated with grade, that can then be represented in multiple ways to show G, T, and GT as well as cumulative tonnage and average grade at any desired cut-off. Multiple and rapid iterations are possible.
- Standard 3D block modeling allows for multiple ways to assign resource classification, at the appropriate SMU, and to the degree of confidence necessary for mine planning. 3D representations of the distribution of grades appropriate for the deposit type and style of mineralization can be generated. And 3D representations of controlling geology and geologic factors affecting recovery can be incorporated. These are stated "best practices" by both CIM and JORC reporting codes.
- Some ISR mine planning software uses GT information, so computed GT information is useful. GT representations of zones of mineralization or combined zones of mineralization, and the thickness of mineralized and non-mineralized zones can be generated such that a GT variable can be computed at the desired grid density (not just at each drillhole), which allows for the application of cutoffs appropriate for mine planning. The estimated grades for the resultant mine planning GT models are derived from the initial 3D estimations, with grades being subsequently aggregated for a given zone. Thickness of the mineralized zone can be determined independently from the 3D geologic model.

To summarize, the utilization of industry standard 3D modeling allows for:

- The application of internationally accepted confidence classifications appropriate for most mineral deposits, which should include uranium deposits;
- Flexibility in the evaluation of resources with alternative cutoffs based on grade, thickness or grade thickness product. Sensitivities to various factors can be readily examined;
- The ability to incorporate 3D representations of controlling geology and geologic factors related to recovery, which along with the 3D representation of grade and thickness, will be the basis for mine planning; and
- Resource information in a digital form that can be provided to the mining investment community in a manner that will allow detailed third- party examination (audits) of the resource.

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(with input from Frank Daviess)

Following: Example images of drilling on 100-150 ft spacing and 50 x 50 x2ft block model representations of Grade and GT.

Example Plan maps

Figure 1: GT Contour Plan Map – Sandstone-hosted tabular uranium deposit, drillhole cumulative grade x thickness (GT).

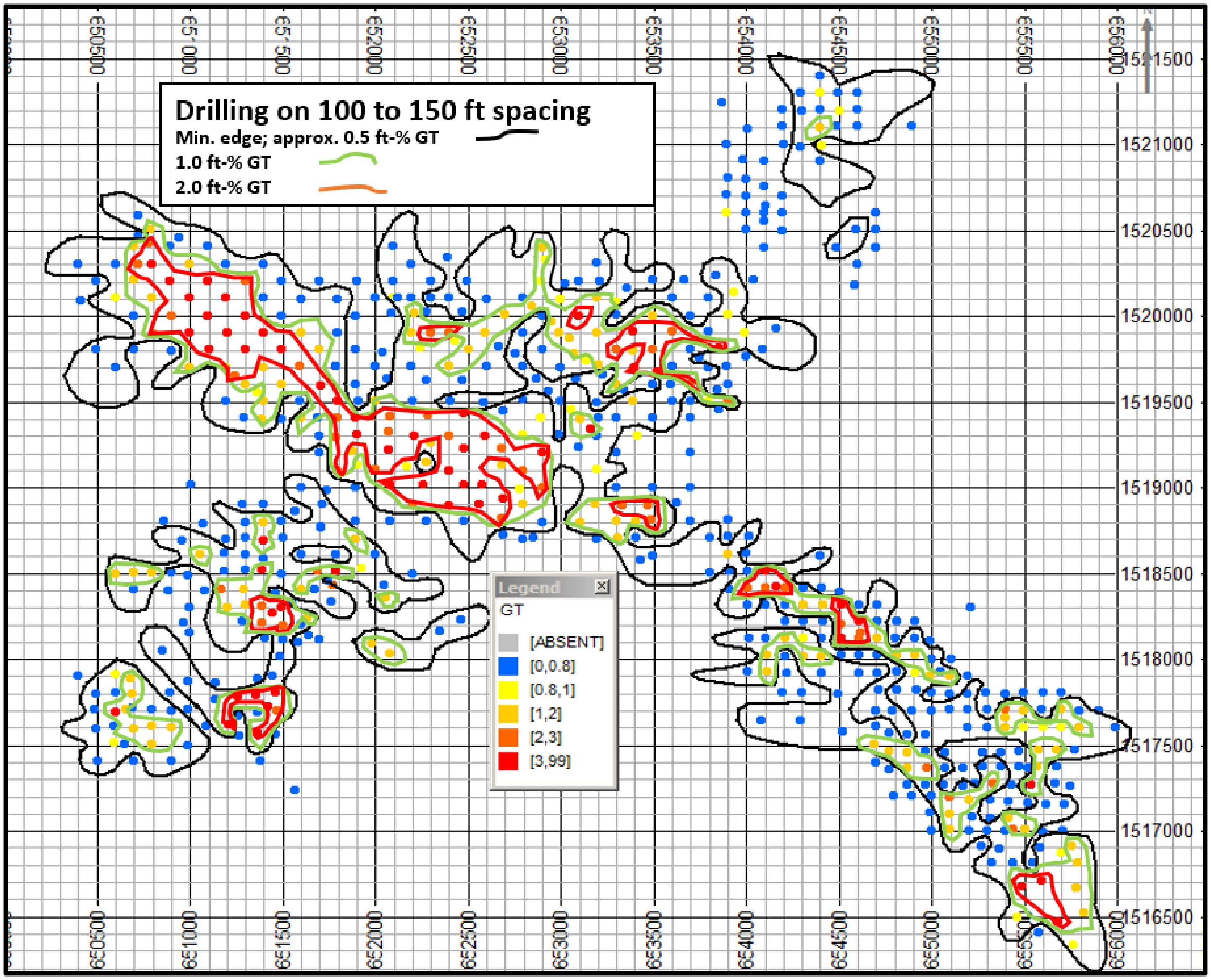

Figure 2: eU_3O_8 Grade Plan Map – Sandstone-hosted tabular uranium deposit, cumulative average grade

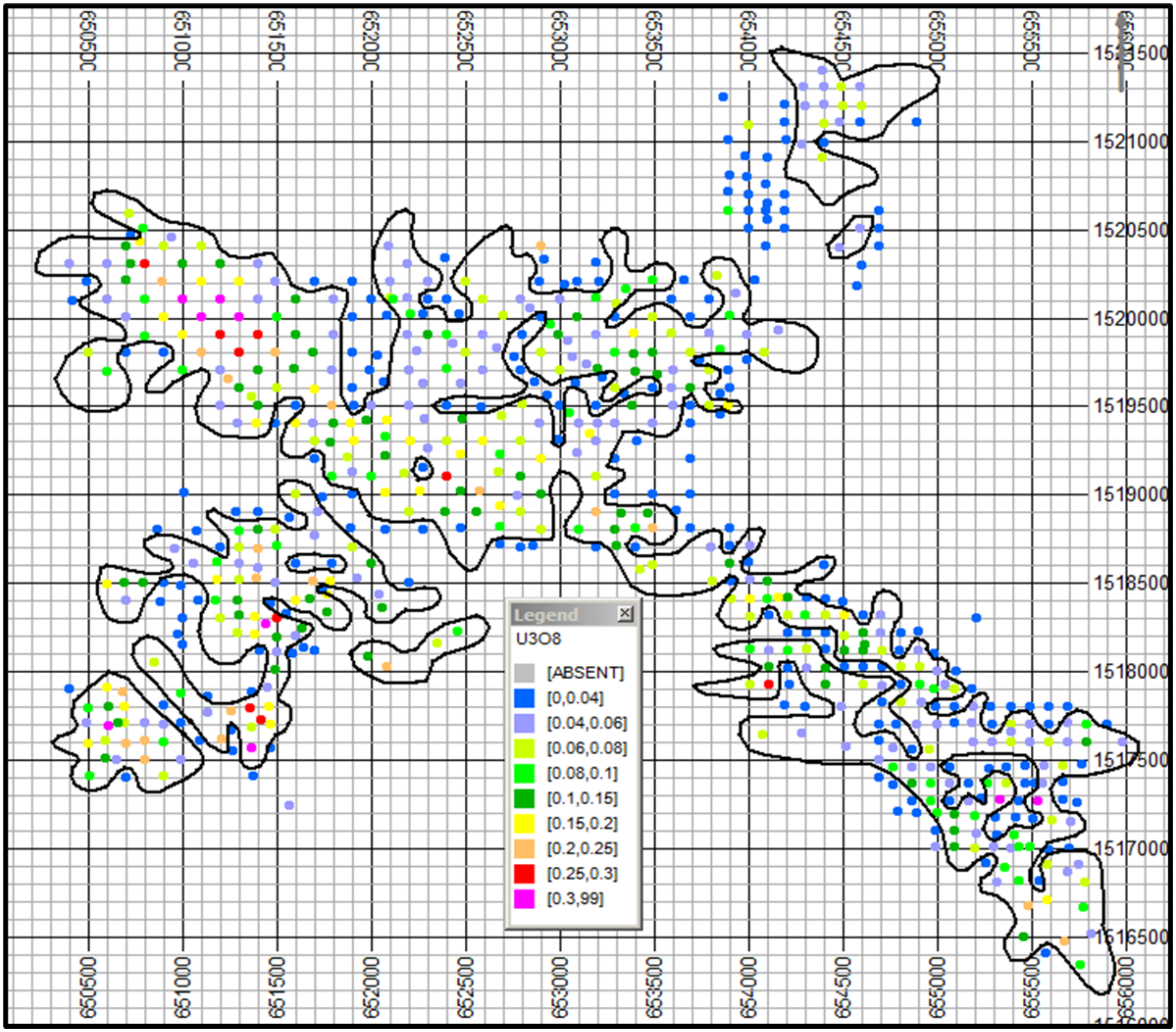

Figure 3: 3D Block Model Plan Map – Estimated Grade 50 x 50 x 2 ft blocks

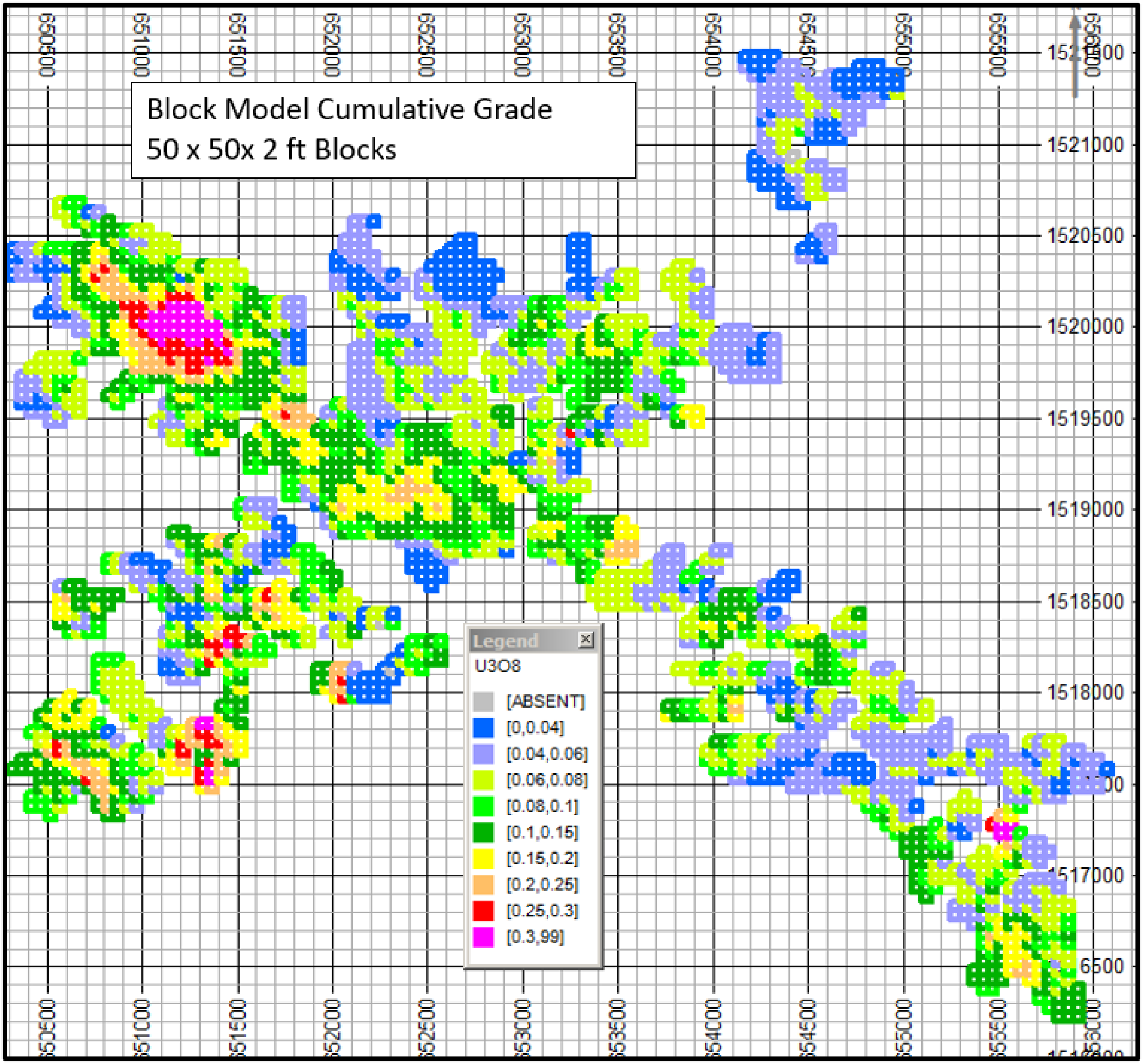

Figure 4: 3D Block Model Cumulative GT 50 x 50 x 2 ft blocks

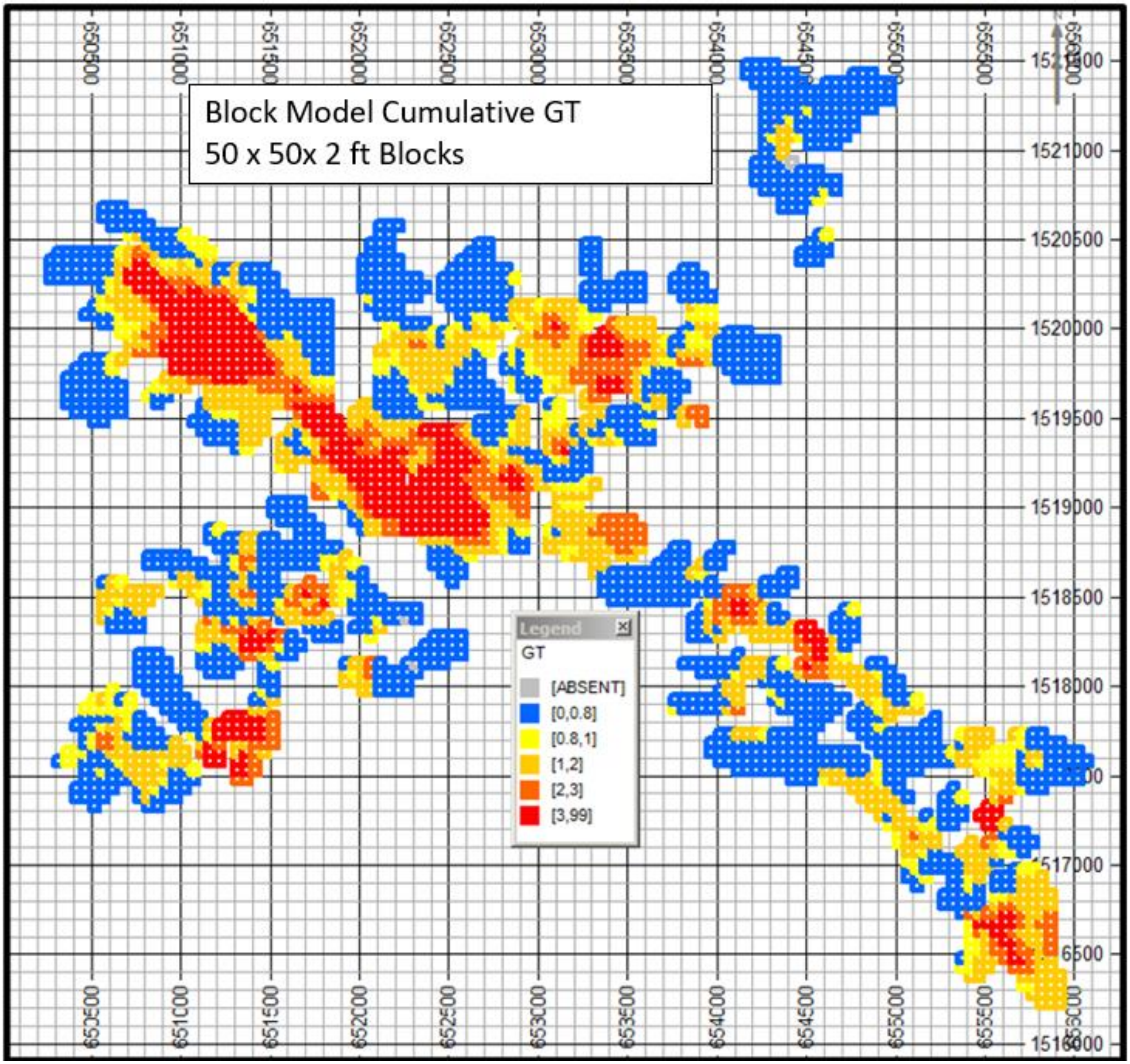

Figure 6: Representative Cross-Section showing Block grades versus drillhole grades